Science

[UNDER REVISION.]

Science and Art Department of the Committee of Council on Education.

CATALOGUE

OF THE

SPECIAL LOAN COLLECTION OF SCIENTIFIC APPARATUS

AT THE

SOUTH KENSINGTON MUSEUM.

MDCCCLXXVI.

SECOND EDITION.

LONDON:
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PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1876.

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SCIENCE AND ART DEPARTMENT OF THE COMMITTEE OF COUNCIL ON EDUCATION.

SOUTH KENSINGTON.

ESTABLISHED in connexion with the Board of Trade in March 1853 as a development of the Department of Practical Art, which in 1852 had been created for the re-organisation of Schools of Design. Placed under the direction of the Committee of Council on Education in 1856.

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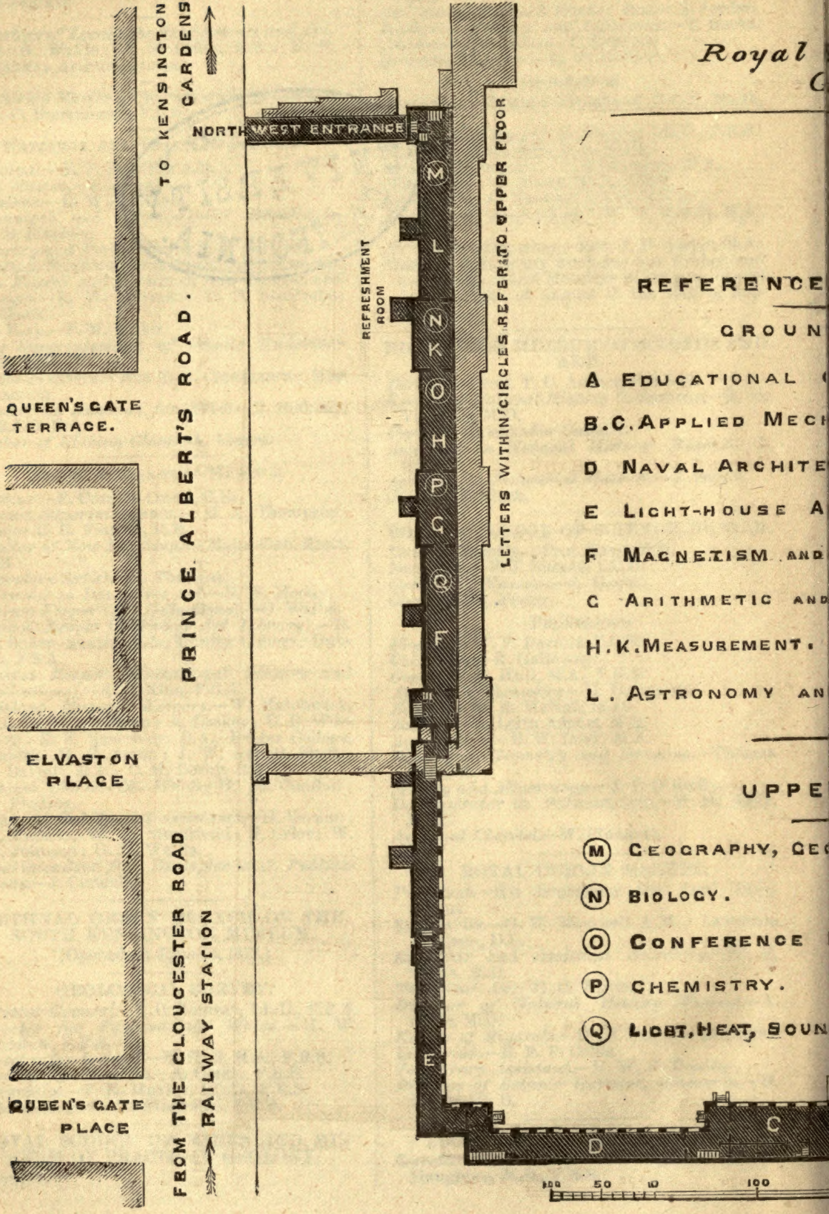
SOUTH KENS

LOAN COLLECTION OF SC

PLAN OF GALLERIES LENT BY H.M.



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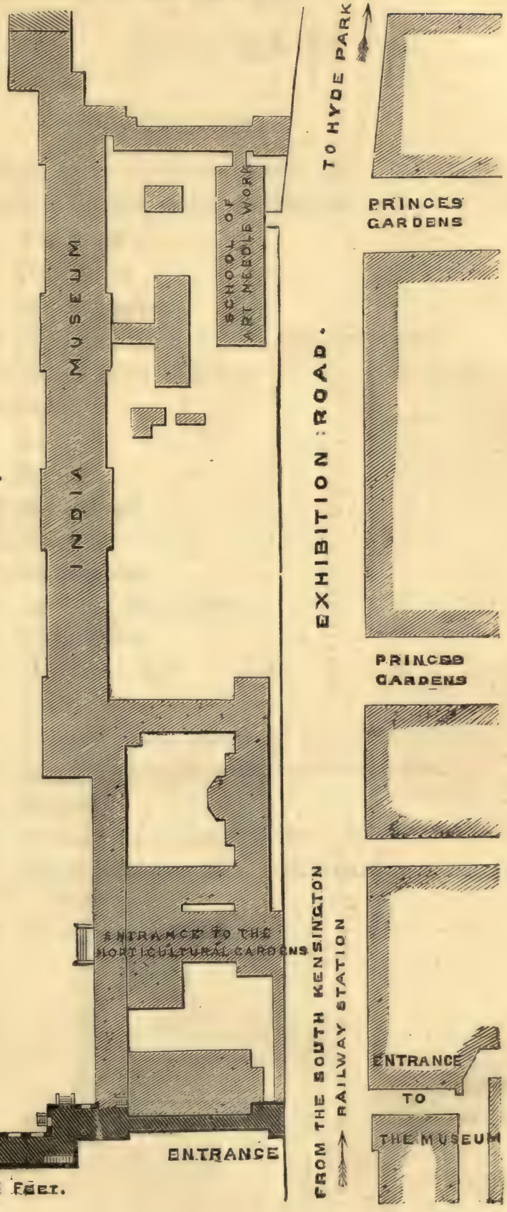

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...Y, AND MINING.

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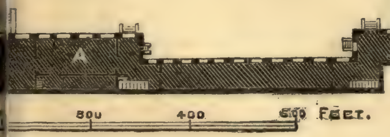

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INTRODUCTION.

By Minute dated 22nd January 1875, the Lords of the Committee of Council on Education approved of a proposal to form a Loan Collection of Scientific Apparatus, which was to include not only apparatus for teaching and for investigation, but also such as possessed historic interest on account of the persons by whom, or the researches in which, it had been employed. Their Lordships then invited some of the leading men of science of the country—the Presidents of the learned Societies and others—to act on a Committee to consider the matter, and aid them with their advice. This Committee, to whose exertions the formation of the collection is so largely due, consisted of—

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Mr. G. R. Stephenson, President of the Institution of Civil Engineers.
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Dr. W. H. Stone.
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Rev. J. F. Twisden, M.A.
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Sir C. Wheatstone, F.R.S. (since deceased).
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Professor A. W. Williamson, Ph.D., F.R.S.
Mr. Bennet Woodcroft, F.R.S.
Dr. J. Woolley, F.R.S.
Colonel H. Stuart Wortley.

The first meeting of this Committee was held on the 13th February 1875; the number of those who were present showing the interest already felt in the subject. The Lord President of the Council, the Duke of Richmond, and the Vice-President, Viscount Sandon, in explaining the objects of the Collection, took occasion to refer to the recommendations of the Royal Commission on Scientific Instruction, with regard to the creation of a Science Museum.

Their Lordships stated their conviction that the development of the Educational, and certain other, Departments of the South Kensington Museum, and their enlargement into a Museum somewhat of the nature of the *Conservatoire des Arts et Métiers* in Paris, and other similar institutions on the Continent, would tend to the advancement of science, and be of great service to the industrial progress of this country. While expressing their hope that the Loan Collection might forward this desirable object, their Lordships guarded themselves against committing Her Majesty's Government, which had not yet fully considered the subject, to any definite scheme.

On the motion of the President of the Royal Society, Dr. Hooker, it was unanimously resolved by the meeting that an exhibition such as that proposed would be most instructive and valuable.

The question of the limits of the collection were discussed, and Sub-Committees were appointed to consider the limitations it might be desirable to place on the term "scientific apparatus" in the respective sections, while bearing in mind the space disposable for the exhibition in the Museum. As a provisional arrangement five Sub-Committees of sections were appointed, to whom it was left to suggest such modifications in classification as might be found advisable.

The sections were—

1. Mechanics (including pure and applied mathematics).
2. Physics.
3. Chemistry (including metallurgy).
4. Geology, Mineralogy, and Geography.
5. Biology.

The Committees for the several sections are given at page xxi.

The question of classification, having been carefully considered at numerous meetings of these Sub-Committees, was brought before the General Committee on the 12th May, and the several schemes were referred to a special Sub-Committee, formed of three members from each sectional Sub-Committee. It was also decided to postpone the Exhibition, which it was originally intended to open in June 1875, to March 1876. The large number of objects sent from abroad, and the late period of their arrival, have necessitated a further postponement of the opening to May 1876.

The Sub-Committee appointed to revise and report on the classification of the Collection after three meetings, under the chairmanship of the President of the Royal Society, submitted a scheme of classification to the General Committee on June 22nd. After having been carefully considered, it was, with some slight alterations, approved, and is given at page xv. This programme was immediately issued, and the classification into sections is that adopted for the catalogue and exhibition, though the nature of the Galleries has necessitated some alteration in the order of the sections.

It had been the intention from the first to give the Loan Collection an international character, so as to afford men of science and those interested in education an opportunity of seeing what was being done by other countries than their own in the production of apparatus, both for research and for instruction—an opportunity which it was hoped would be of advantage also to the makers of instruments. As soon, therefore, as the programme had been definitely settled, steps were taken to interest foreign countries in the Exhibition; and it was determined to obtain the co-operation of men of science on the Continent, who, while acting as members of

the General Committee, should form special Sub-Committees charged with the due representation of the science of their respective countries.

It was necessary to take special precautions to prevent misunderstanding as to the character of the Collection. The mention of internationality at once suggested the idea of an International Exhibition similar in its character and arrangements to the numerous Industrial Exhibitions which have been held in various countries. A wrong impression of this kind would have entailed serious inconvenience.

In International Exhibitions a certain amount of space is allotted to each country. These spaces are then divided by the Commissioners of each country among its exhibitors, who display their objects—subject to certain general rules of classification—as they consider most advantageous, retaining the custody of their own property. The expenses of transport, arrangement, &c., are borne by the countries who exhibit. And the Exhibitions appeal naturally, more or less exclusively, to the industrial or trade-producing interests of those countries.

This was not the idea of the proposed Loan Collection at South Kensington. For that Collection it was desired to obtain not only apparatus and objects from manufacturers, but also objects of historic interest from museums and private cabinets, where they are treasured as sacred relics, as well as apparatus in present use in the laboratories of professors. The transport of all objects was undertaken by the English Government, and they were to be handed over absolutely to the custody of the Science and Art Department for exhibition; the arrangement being not by countries but strictly according to the general classification.

So soon as the object and scope of the Collection were thoroughly understood, the Committee of Council on Education met with the most gratifying responses to their invitations, which were communicated officially through the Foreign Office. Her Majesty's Ministers at Paris, Berlin, St. Petersburgh, Vienna, Florence, Brussels, the Hague, Stockholm, Madrid, Berne, and Washington, have personally interested themselves in the matter. And the Foreign Governments have afforded every facility and encouragement in forwarding this strictly international undertaking.

The subjoined list of the foreign members of the General Committee speaks for itself by the eminence and European reputation of its members.

BELGIUM.

M. Stas, Membre de l'Académie Royale (President).

M. le Général Brialmont, Président de l'Académie Royale et Inspecteur Général du Génie.

M. Dewalque, Membre de l'Académie Royale, Professeur de Géologie et de Minéralogie à l'Université de Liége.

M. Maus, Membre de l'Académie, Inspecteur Général des Ponts et Chaussées.

M. Plateau, Membre de l'Académie Royale, F.R.S.

M. Schwann, Membre de l'Académie Royale, Professeur à l'Université de Liége.

M. Van Beneden, Membre de l'Académie et Professeur à l'Université de Louvain, F.R.S.

M. le Général Liagre, Secrétaire perpétuel de l'Académie Royale, et Commandant et Directeur des Études de l'École Militaire (Secretary).

FRANCE.

M. le Général Arthur Jules Morin, Membre de l'Académie des Sciences, Directeur du Conservatoire des Arts et Métiers (President).

M. Alexre. Edmond Bécquerel, Membre de l'Académie des Sciences, Professeur au Conservatoire des Arts et Métiers, F.R.S.

M. Henri Marie Bouley, Membre de l'Académie des Sciences, Inspecteur Général des Écoles Vétérinaires.

M. Gabriel Auguste Daubrée, Membre de l'Académie des Sciences, Directeur de l'École des Mines.

M. Jean Louis Armand de Quatrefages de Bréau, Membre de l'Académie des Sciences, Professeur au Museum d'Histoire Naturelle.

M. Jean Baptiste Dumas, Secrétaire perpétuel de l'Académie des Sciences, F.R.S.

M. Hervé Auguste Etienne Albans Faye, Membre de l'Académie des Sciences, Président du Bureau des Longitudes.

M. Edmond Frémy, Membre de l'Académie des Sciences, Professeur au Museum d'Histoire Naturelle.

M. Jules Célestin Jamin, Membre de l'Académie des Sciences, Professeur á l'École Polytechnique.

M. Lenglet, Consul Général de France à Londres.

M. Urbain Jean Joseph Le Verrier, Membre de l'Académie des Sciences, Directeur de l'Observatoire, F.R.S.

M. Eugène Melchior Peligot, Membre de l'Académie des Sciences, Directeur des Essaisà la Monnaie.

M. Henri Edouard Tresca, Membre de l'Académie des Sciences, Sous-Directeur du Conservatoire des Arts et Métiers (Secretary).

GERMANY.

I.—Berlin Committee.

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Dr. Beyrich, Professor of Geology.

Dr. du Bois-Reymond, Professor of Physiology.

Dr. Dove, Professor of Physics, F.R.S.

Dr. Förster, Director of the Observatory.

Dr. Hagen, President of the Board of Works.

T. G. Halske, Telegraphic Engineer.

Dr. Hauchecorne, Director of the School of Mines.

Dr. Helmholtz, Professor of Physics, F.R.S.

Dr. Kiepert, Professor of Geography.

Dr. G. Kirchhoff, Professor of Physics, F.R.S.

Dr. Kronecker, Professor of Mathematics.

Dr. C. D. Martius, Chemist.

Von Morozowicz, General.

Dr. Neumayer, Hydrographer of the Imperial Admiralty.

Dr. Reuleaux, Director of the Polytechnic Academy.

Dr. Schellbach, Professor of Mathematics.

Dr. Werner Siemens, Telegraphic Engineer.

Dr. Virchow, Professor of Pathology.

Dr. C. H. Vogel, Astronomer.

Dr. Websky, Professor of Mineralogy.

II.—Committee representing other Cities and Towns of Germany.

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Dr. Beetz, Professor of Physics, Munich.

Dr. Buff, Professor of Physics, Giessen.

Dr. Clausius, Professor of Physics, Bonn, F.R.S.

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Dr. Von Feilitzsch, Professor of Physics, Greifswald.

Dr. Graebe, Professor of Chemistry, Königsberg.

Dr. Von Groddeck, Director of the School of Mines, Klausthal.

Dr. Heeren, Professor of Chemistry, Hanover.

Dr. Hittorf, Professor of Chemistry, Münster.

Dr. Karsten, Professor of Physics, Kiel.

Dr. Karsten, Professor of Physics, Rostock.

Dr. Knapp, Professor of Chemistry, Braunschweig.

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Dr. Wöhler, Professor of Chemistry, Göttingen, F.R.S.

Dr. Wüllner, Professor of Physics, Aachen.

Dr. Zeuner, Director of the Polytechnic School, Dresden.

Dr. Zetzsche, Director of the Polytechnic School, Chemnitz.

ITALY.

Il Com. Blaserna, Professor of Physics and Rector of the Royal University of Rome.
Il Com. Cantoni, Professor of Physics at the Royal University of Pavia.
Il Cav. Respighi, Professor of Astronomy in the Royal University of Rome, and Director of the Observatory of the Campidoglio.

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Professor Dr. C. H. D. Buys Ballot.
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Professor Dr. J. W. Gunning.
Professor Dr. R. A. Mees.
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Dr. D. de Loos, Director of the Secondary Town-School of Leyden (Secretary).

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M. Beilstein, Professeur de l'Institut technologique.
M. Barbot de Marny, Professeur de l'Institut des Mines.
M. Koulibine, Professeur de l'Institut des Mines.

SWITZERLAND.

Professor E. Wartmann (President).
Professor J. Amsler Laffon.
Professor D. Colladon-Adòr.
Professor Dr. F. A. Forel.
Professor Dr. E. Hagenbach-Bischoff.
Professor Ad. Hirsch.
Professor Albert Mousson.
M. E. Sarasin-Diodati.
Professor L. Soret.
Colonel Gautier (Secretary).

AUSTRIA AND HUNGARY.

The Minister of Public Instruction has appointed Sectionschef Fidler to organise the contributions from these countries.

SPAIN.

No committee has been formed, but the Government has promised to contribute, and Señor Riano has been specially appointed to make the necessary arrangements.

UNITED STATES.

The Government has, through Mr. Fish, replied that it is in communication with the various departments and scientific institutions with the object of forwarding the Exhibition.

When men of this position in all branches of science have given their adhesion to the programme of such an Exhibition, its success might well be considered as secured. But these gentlemen did not rest satisfied with merely giving their names in recognition of its value: they have spared no time and labour in making the undertaking a real success. And the Lords of the Committee of Council on Education feel assured that, in offering them their thanks for their invaluable services, they convey not only their own sentiments but the grateful recognition of their labours by the country at large.

It will be readily understood from what has been said of the nature, scope, and method of the Exhibition that a large staff was required, in addition to the permanent staff of the Museum, to organise and arrange the collection in the limited time which could be afforded for that purpose. Special arrangements had, therefore, to be made; and their Lordships have great satisfaction in recording the names of those gentlemen who have rendered very valuable services—many of them as volunteers—greatly aiding the staff of the Museum in their laborious duties. These were Captain Abney, R.E.; Dr. Atkinson; Mr. Bartlett; Dr. Brunton; Dr. Biedermann; Professor Crum-Brown; Captain Fellowes, R.E.; Professor Carey Foster; Dr. Michael Foster; Herr Kirchner; Professor Goodeve; Dr. Guthrie; Commander T. A. Hull, R.N.; Mr. Iselin; Mr. Judd; Mr. Norman Lockyer; Dr. R. J. Mann; Mr. Clements Markham; Professor H. MacLeod; Professor Roscoe; Professor Shelley; Dr. Burdon Sanderson; Dr. Schuster; Dr. Voit; and Mr. R. Wylde.

To those men of science, who, in this matter and in the work of the General Committee and Sub-Committees, have given much valuable time, and have afforded them the benefit of their great knowledge and experience, the Lords of the Committee of Council on Education feel their best thanks are due, and they trust that the immediate success and future results of the Exhibition, which owes so much to

them, will reward them for the labours which they have ungrudgingly devoted to it.

In order to make the Collection as useful and interesting as possible, a Handbook containing introductory notices to the several sections has been prepared. For writing these notices the Lords of the Committee of Council on Education have been fortunate in securing the services of gentlemen the mention of whose names will be a sufficient indication of the character of the work. These gentlemen are—

Capt. W. de W. Abney, R.E.
Professor W. Kingdon Clifford, M.A., F.R.S.
Capt. J. E. Davis.
Professor G. Carey Foster, B.A., F.R.S.
Professor Geikie, F.R.S.
Professor Goodeve, M.A.
Professor Guthrie, F.R.S.
Professor T. H. Huxley, LL.D., Secretary of the Royal Society.
Mr. J. Norman Lockyer, F.R.S.
Professor MacLeod.
Mr. Clements Markham, C.B., F.R.S.
Mr. N. Story Maskelyne, M.A., F.R.S.
Professor J. Clerk Maxwell, M.A., F.R.S.
Mr. R. H. Scott, M.A., F.R.S.
Professor H. J. S. Smith, M.A., F.R.S.
Mr. W. Warington Smyth, M.A., F.R.S.
Mr. H. C. Sorby, F.R.S.
Mr. W. Spottiswoode, M.A., LL.D., F.R.S.
Dr. W. H. Stone.
Professor P. G. Tait, M.A.

It had been originally proposed to exhibit the Collection of Scientific Apparatus in the South Kensington Museum; but various circumstances, which could not be foreseen, having rendered it necessary to abandon this intention, Her Majesty's Commissioners for the Exhibition of 1851, most liberally placed the galleries on the western side of the Horticultural Gardens at the disposal of the Science and Art Department. Though, unfortunately, these galleries are disconnected from the Kensington Museum, they are admirably adapted to the present purpose, and afford an accommodation which could not otherwise have been obtained.

By order,

F. R. SANDFORD,

Secretary, Committee of Council on Education.

CLASSIFICATION OF THE COLLECTION.

Arithmetic.

Apparatus for teaching arithmetic. — Calculating machines.—Instruments for solving equations.—Slide rules.—Numbering and enumerating apparatus, &c.

Geometry.

Instruments used in geometrical drawing.—Methods of copying—Pantigraph, micrograph.—Peaucellier's cell and parallel motion—Machines for description of curves and specimens of the curves they describe, including geometric turning.—Instruments for giving graphic representations of phenomena.—Models to illustrate descriptive geometry.—Specimens to illustrate the process of making models according to a design.—Models to illustrate solid geometry, perspective, crystallography, &c. -- Stereoscopic illustrations of solid geometry.

Measurement.

Of length.—Standard yard, metre, &c.—Comparator for standards of length (sight and touch). — Gauges, measuring wheels, steel tapes, &c.—Micrometers and verniers.—Cathetometers.

Of area.—Planimeters, &c.

Of volume.—Standard gallon, litre, &c. — Pipettes, burettes.—Meters for gas, water, &c.

Of angles. — Divided circles, theodolites, clinometers, goniometers, &c.

Of mass.—Standard pound, kilogramme, &c. — Vacuum and other balances.

Of density.—Specific gravity bottles, areometers, &c.

Of time.—Clocks and pendulums, chronometers, watches, and balance wheels.—Tuning forks for measuring small intervals of time.—Chronographs.

Of velocity.—Such as Morin's machine.—Strophometers, current meters, ships' logs, &c.

Of momentum.—Ballistic apparatus.

Of force.—Spring balances, pressure gauges, torsion balances, &c.

Of work.—Indicators, dynamometers, &c.

Kinematics, Statics, and Dynamics.

Elementary illustrations.—Position and displacement of a point, a rigid body, or a material system.—Composition and resolution of displacements.—Velocity and acceleration, their composition and

resolution.—Displacements of a connected system.—Principles of mechanism.—Rolling contact, sliding contact, belting, link connexions, shafting, universal joints, &c.—Transmission of work.—Relation between the displacement of two pieces of a machine and the forces which they transmit.—The mechanical powers.—Instruments for illustrating the laws of motion, such as pendulums, gyroscopes, dynamical tops.

Laws of fluid pressure; stability of floating bodies.

Discharge of fluids through orifices, and their motion in channels.

Hydraulic and pneumatic transmission of power.

Molecular Physics.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with :—

Pressure on Matter.—Tension, Compression (piezometer) Torsion, Flexion; Relation of volume to pressure; Elasticity of liquids and gases.—Hardness (of solids and liquids), Toughness, Brittleness, Malleability, &c.

Communication of Pressure through Fluids.—Pressure of air, its consequences and applications.—Barometers, Air-pumps, Siphons, Suction-pumps, Spirators, &c.; Pressure of water, its consequences and applications,—Levels, Side pressure, &c.

Density.—Methods of measuring densities of Gases, Vapours, Liquids, Solids.

Adhesion and Cohesion.—Condensation of gases in solids, Solution of gases in liquids, Mixing of gases with gases (Diffusion, Transpiration, &c.), Absorption of liquids by solids (Capillarity, &c.), Absorption of liquids by gases (Evaporation, &c.), Mixing of liquids with liquids (Osmose, Diffusion Dialysis).—Evaporation of solids, Solution of solids, Mixture of solids with solids (Cementation, &c.).

Sound.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with :—

Geometrical, Mechanical, and Optical methods of Illustrating the Laws of Wave Motion.—Progressive waves, Composition of Vibrations, Interference, Stationary waves.

Generation of Sound.—Fog-horn, &c.

Conduction of Sound.—Through solids, liquids, and gases, Stethoscopes.

Velocity of Sound.

Detection of Sound.—Sensitive flame, &c.

Reflexion and Refraction.—Ear trumpets, Acoustic lenses, &c.

Dispersion and Absorption.

Musical Sounds.—Pitch, Standards of Pitch, Standard Tuning Forks, &c.; Methods of measuring and comparing rates of vibration; Toothed wheels, Syrens, &c.; Vibration Microscopes, &c.; Methods of illustrating the nature of musical intervals; Manometric flames, Mirrored Tuning Forks, &c.

Musical Quality.—Illustrations of the different quality of the sounds of various instruments, Harmonics, and overtones, Resultant tones, Instruments for studying quality, Resonators, Phonautographs, &c.

Musical Instruments Illustrating the above.—Methods of exhibiting the mode of vibration of various instruments and the quality of the sounds yielded by them.

Light.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with:—

Production.—Combustion, Electric discharge, &c.

Measurement of Intensity, Velocity.

Action of Matter on Light.—Reflection, Refraction, Dispersion, Achromatism, Direct vision prisms, Polarization, Absorption (colour), Fluorescence, &c.

Action of Light on Light.—Interference, Diffraction, Measurement of wave length (optical banks), &c.

Action of Light on Matter.—Photography, Radiometry, Phosphorescence, &c.

Technical Applications of Optical Principles.—Lighthouse-illumination, &c.

Heat.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with:—

Sources of Heat.—Chemical, Electrical, Dynamical, Solar, Calorescence, &c.

Effects of Heat on Matter.—Changes of Temperature, Expansion and change of Elasticity, Liquefaction, Vaporization, &c.

Measurement of Temperature.—Thermometers, Pyrometers, &c.

Propagation of Heat.—Radiant Heat,—Radiometer, Reflexion, Refraction, Radiation, Absorption, Polarization; Conduction,—Solids, Liquids, Gases; Convection,—Ventilation, &c.

Effect of change of Molecular State on Temperature.—Freezing mixtures, Ice machines, &c.

Effect of change of Pressure and Volume.

Heat Quantity.—Unit of Heat, Calorimeters, Specific Heat, &c. Methods of determining Latent Heat.

Mechanical Equivalent of Heat.—Methods of determining. Illustrations of Thermodynamics.

Electrical Equivalent of Heat.—Methods of determining.
Analysis of Solar Radiation.

Magnetism.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with :—

Natural Magnets.
Permanent Artificial Magnets.
Electro-Magnets.

Methods of Magnetization.—Effects of Magnetization. Conditions affecting intensity of Magnetization :—Temperature (chemical), Composition, Strains, &c.

Magnetic Induction of all Substances.—Diamagnetism.

Measurement of Intensity of Magnetization, Magnetic moment.

Terrestrial Magnetism.—Instruments for observation and automatic registration of the magnetic elements.

Electricity.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with :—

Production and Maintenance of Difference of Potential.—Electrical machines acting by friction, induction (doublers, replenishers, &c., Holz's and Töppler's machines, &c.) ; Galvanic batteries ; Thermo-electric piles ; Magneto-electric machines. Other sources, such as Pyro-electricity, Pressure electricity, Cleavage, Capillarity, Osmose, &c.

Detection and Measurement of Difference of Potential.—Electroscopes, Electrometers, Standards of electro-motive force, Methods of comparison.

Accumulation of Electricity.—Insulators, Condensers, Accumulators, Effects due to accumulated electricity, Distribution on conductors, Polarization of dielectrics, &c.

Measurement of Electric Quantity.—Torsion balances, Standard accumulators, Methods of comparing electric capacities and dielectric coefficients.

Detection and Measurement of Electric Currents.—Galvanoscopes, Galvanometers, Voltameters, Electro-dynamometers, &c.

Resistance.—Standards of resistance, Methods of comparing resistances, Methods of establishing absolute standards (British Association unit appar.).

Effects of Electric Currents.—Production of light, heat, Electrolysis, Electro-diffusion. Action on magnets, soft iron (electro-magnets), Action of currents on currents.

Technical Application of Electricity.—Electric telegraph, &c.

Astronomy.

Star maps, catalogues, globes, orreries, &c.
Meridian instruments.
Arrangements for communicating true time.
Altazimuths, zenith-sectors, sextants, &c.
Equatoreal Telescopes $\left\{\begin{array}{l}\text{Reflectors.}\\\text{Refractors.}\end{array}\right.$
Micrometers.
Driving clocks.
Special arrangements for—
  Celestial photography.
  Spectroscopic observations.
  Thermo-electric observations.
Siderostats.

Applied Mechanics.

As the Exhibition must be regarded as chiefly referring to education, research, and other scientific purposes, it must in this division consist principally of models, diagrams, mechanical drawings, and small machines, illustrative of the principles and progress of mechanical science, and of the application of mechanics to the arts.

Properties of Materials.
Structures at Rest and in Motion.
Prime Movers.
Reservoirs of Energy.
Regulators.
The Application of the Principles of Mechanics to Machinery as used in the Arts.
Shipping, Naval Architecture, and Marine Engineering.

Chemistry.

Scientific instruments, apparatus, and materials employed in the investigation and teaching of Chemical Science, and in the application of its principles to scientific purposes.

Diagrams and models.
Illustrations of analytical results.
Specimens of chemicals,—(*a*) organic, (*b*) mineral.
Apparatus and fittings for laboratory and lectures.
Apparatus for gravimetric and volumetric operations.
Apparatus for distillation and filtration.
Apparatus for operations by the dry or hot method, such as furnace, blowpipe, &c.
Refrigeratory apparatus.
Apparatus for spectrum analysis.

NOTE.—Operations of the following nature may be illustrated, viz.:

Organic analysis.
Mineral analysis.
Electrolysis.
Water analysis.
Gas analysis.
Spectrum analysis.
Methods of investigation connected with vegetation and respiration.

Meteorology.

Thermometers and barometers, of special construction.
Anemometers, rain gauges, hydrometers, &c.
Self-recording meteorological apparatus.
Illustrations of various systems of storm signals.
Weather maps.
Instruments illustrating the phenomena of atmospheric electricity.
Instrument stands.

Geography.

Instruments used in surveying.
Instruments used in Geodesy and Hydrography, including hypsometrical instruments, tide gauges, &c.
Projections, maps, charts, models, and globes.
Deep-sea sounding apparatus. Seismographical instruments.

Geology and Mining.

Instruments for field and underground surveying.
Typical collections of rock specimens, including vein stones.
Typical fossils arranged stratigraphically.
Maps in different stages, and finished maps.
Geological models, horizontal and vertical sections.
Diagrams and plates of fossils, and general geological diagrams used in lecture rooms.
Microscopic sections of rocks and minerals, and apparatus for cutting such sections.
Anemometers, water gauges, mining barometers, and thermometers.
Mining plans, sections, and models of workings.

Mineralogy, Crystallography, &c.

Goniometers.
Apparatus for studying and exhibiting the optical characters of crystals.

Sections for optical examination.

Blowpipe and other portable apparatus for determining minerals.

Collections of crystals, models of crystals, plates of crystals, and apparatus for drawing them.

Educational collections of minerals, &c.

Diagrams and models for lecture rooms.

Biology.

1. Microscopes with accessory apparatus for biological research, &c.
2. Physiological apparatus for investigating—
   a. The growth and mechanical movements of living organisms and their parts.
   b. The chemical phenomena of living organisms.
   c. The electrical phenomena of living organisms.
   d. The functions of the nervous and other systems.
3. Apparatus for anatomical research.
4. Apparatus for collecting and preserving object of natural history.
5. Appliances for teaching biology.

A limited number of examples illustrating the performances of the apparatus will be admissible.

Sub-Committees of Sections.

SECTION I.—MECHANICS, INCLUDING PURE AND APPLIED MATHEMATICS AND MECHANICAL DRAWING.

Professor J. C. Adams, M.A., F.R.S.
Mr. J. Anderson, LL.D., C.E.
Professor R. Stawell Ball, LL.D., F.R.S.
Rev. A. Barry, D.D.
Mr. W. B. Baskcomb.
Mr. Hugh Birley, M.P.
Major Bolton.
Professor F. A. Bradley.
Mr. F. J. Bramwell, F.R.S.
Mr. T. Brassey, M.P.
Mr. H. W. Chisholm, Warden of the Standards.
Mr. G. T. Clark.
Mr. Latimer Clark.
Professor R. B. Clifton, M.A., F.R.S.
Sir Henry Cole, K.C.B.
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Major-General F. Eardley-Wilmot, R.A., F.R.S.
Mr. D. Glasgow.
Professor T. M. Goodeve, M.A.
The Right Hon. Lord Hampton, G.C.B., F.R.S., President of the Institute of Naval Architects.
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Mr. C. W. Merrifield, F.R.S.
Mr. A. J. Mundella, M.P.
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Mr. J. Scott Russell, F.R.S.
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Professor H. J. S. Smith, M.A., F.R.S.

Mr. G. R. Stephenson, President of the Institute of Civil Engineers.
Professor P. G. Tait, M.A.
Mr. J. Torr, M.P.
Rev. J. F. Twisden, M.A.
Professor W. C. Unwin, B.Sc.
Sir C. Wheatstone, F.R.S. (since deceased).
Sir J. Whitworth, Bart., F.R.S.
Mr. Bennet Woodcroft, F.R.S.
Dr. J. Woolley, F.R.S.
Colonel H. Stuart Wortley.

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Capt. W. de W. Abney, R.E.
Professor W. G. Adams, M.A., F.R.S.
Sir G. B. Airy, K.C.B., D.C.L., F.R.S., Astronomer Royal.
Professor E. Atkinson, Ph.D.
Professor R. Stawell Ball, LL.D., F.R.S.
Professor W. F. Barrett.
Mr. C. Brooke, M.A., F.R.S.
Mr. C. O. F. Cator.
Mr. W. Chappell.
Professor R. B. Clifton, M.A., F.R.S.
Vice-Admiral Sir R. Collinson, K.C.B., Deputy Master of the Trinity House.
Dr. Debus, F.R.S.
Mr. Warren De La Rue, D.C.L., F.R.S.
Mr. H. S. Eaton, President of the Meteorological Society.
Professor G. Carey Foster, B.A., F.R.S., President of the Physical Society.
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Professor Guthrie, Ph.D., F.R.S.
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Lord Lindsay, M.P.
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Dr. R. J. Mann.
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Dr. Pole, F.R.S.
The Right Hon. Lord Rayleigh, F.R.S.
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Earl of Rosse, D.C.L., F.R.S.
Mr. R. H. Scott, M.A., F.R.S.
Mr. W. Spottiswoode, M.A., LL.D., F.R.S.
Dr. W. H. Stone.
Lieut.-Colonel Strange, F.R.S. (since deceased).
Professor P. G. Tait, M.A.
Professor Tyndall, LL.D., F.R.S.
Mr. C. V. Walker, F.R.S., President of Society of Telegraphic Engineers.
Sir C. Wheatstone, F.R.S. (since deceased).
Dr. Woolley.

SECTION III.—CHEMISTRY.

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Professor Bloxam.
Sir Henry Cole, K.C.B.
Mr. Warren De La Rue, D.C.L., F.R.S.
Professor Frankland, Ph.D., D.C.L., F.R.S.
Dr. Gilbert, F.R.S.
Dr. J. H. Gladstone, F.R.S.
Professor Odling, M.A., F.R.S., President of the Chemical Society.
Dr. Percy, F.R.S.
Mr. J. A. Phillips.
The Right Hon. Lyon Playfair, Ph.D., C.B., M.P., F.R.S.
Professor Roscoe, Ph.D., F.R.S.
Dr. W. J. Russell, F.R.S.
Professor Williamson, Ph.D., F.R.S.

SECTION IV.—PHYSICAL GEOGRAPHY, GEOLOGY, AND MINERALOGY.

Mr. D. T. Ansted, M.A., F.R.S.
Mr. H. Bauerman.
Professor F. A. Bradley.
Mr. H. W. Bristow, F.R.S.
Major-General Cameron, C.B., F.R.S.
Mr. C. O. F. Cator.
Vice-Admiral Sir R. Collinson, K.C.B., Deputy Master of the Trinity House.
Professor P. M. Duncan, M.B., F.R.S., President of the Geological Society.

Mr. H. S. Eaton, President of the Meteorological Society.
Sir P. De M. G. Egerton, Bart., M.P., F.R.S.
Mr. R. Etheridge, F.R.S.
Captain Evans, R.N., C.B., F.R.S., Hydrographer of the Navy.
Mr. J. Evans, F.R.S.
Mr. D. Forbes, F.R.S.
Professor Hughes.
Lieut.-General Sir H. James, R.E., F.R.S.
Dr. R. J. Mann.
Mr. N. Story-Maskelyne, M.A., F.R.S.
Mr. C. W. Merrifield, F.R.S.
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Mining and Mechanical Engineers, North of England Institute of, *Newcastle-upon-Tyne*, **16.**

Mitchell, C., & Co., *Newcastle-on-Tyne*, **12.**

Molineux, T., 8, *Park Village, E., London*, **6.**

Moody, W., 2, *Nightingale Vale, Woolwich, Kent*, **12.**

Morison, D. P., 21, *Collingwood Street, Newcastle-upon-Tyne*, **16.**

MORRIS PATENTS ENGINEERING WORKS, 50, *High Street, Birmingham*, **3**.

MORRISON, R. M., *University of Edinburgh*, **13**.

MOTTERSHEAD & CO., *Manchester*, **10**, **19**.

MULLER, HUGO W., F.R.S., **10**.

MULLER, J. A., C.E., 30, *Craven Street, Strand, London*, **3**.

MURRAY, R. C., 69, *Jermyn Street, London*, **7**.

MUSEUM OF KING GEORGE III., *King's College, London*, **5**, **9**, **10**, **14**.

MUSEUM OF PHYSICAL APPARATUS, *King's College, London*, **7**, **8**, **10**.

MUSEUM OF SCIENCE AND ART, *Edinburgh*, **7**, **8**, **9**, **10**, **13**.

MUSPRATT, J., & SONS, *Widnes, Lancashire*, **13**.

MYLNE, R. W., C.E., F.R.S., F.G.S., 21, *Whitehall Place, London*, **16**.

NAPIER AND ETTRICK, LORD, 40, *Queen Anne's Gate*, **1**.

NAPIER, R., *West Shandon, Dumbartonshire, Scotland*, **12**.

NAVAL MUSEUM, ROYAL, *Greenwich, London*, **3**, **11**, **12**, **15**.

NESBITT, A., F.S.A., *Oldlands, Uckfield*, **3**.

NEGRETTI AND ZAMBRA, *Hatton Garden, London*, **15**.

NEWTON, E. T., *Museum of Practical Geology, Jermyn Street, London*, **18**.

NICHOLAS, J., 90, *Brunswick Street, Manchester*, **3**.

NICKOLL, J. J., 36, *St. Mary Axe, London*, **12**.

NICOL, W. J., *University of Edinburgh*, **13**.

NORRIS, W. J., AND BROTHER, *Calder Chemical Works, Sowerby Bridge, Halifax*, **13**.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, *Newcastle-upon-Tyne*, **16**.

NORTHERN LIGHTHOUSES, COMMISSIONERS OF, *Edinburgh*, **12**.

OERTLING, L., *Turnmill Street, London*, **2**, **3**, **5**.

ORDNANCE SURVEY (Maj.-Gen. Cameron, R.E., F.R.S., Director General), *Southampton*, **15**.

ORDNANCE SURVEY OF PALESTINE, 9, *Pall Mall East, London*, **15**.

O'REILLY, PROF. J. P., *Royal College of Science, Dublin*, **7**, **14**, **16**, **17**.

OXFORD, UNIVERSITY OF, **17**.

OXFORD UNIVERSITY MUSEUM, *Oxford*, **16**, **18**.

PALESTINE, ORDNANCE SURVEY OF, 9, *Pall Mall East, London*, **15**.

PASTORELLI, F., 208, *Piccadilly, London*, **3**, **14**, **15**, **16**, **18**.

PATENTS, COMMISSIONERS OF, *Patent Office Museum, South Kensington, London*, **1**, **3**, **9**, **12**.

PEARSON, A. A., 44 *and* 46, *Queen's Place, Leeds*, **11**.

PENDRED, V., *Streatham Hill, Surrey*, **12**.

PERIGAL, H., F.R.A.S., 9, *North Crescent, Bedford Square, London*, **2**, **4**.

PERKIN, W. H., F.R.S., *The Chestnuts, Sudbury, Harrow*, **13**.

PHORSON, P., *Sunderland*, **12**.

PIGOT, PROF. T. F., C.E., M.R.I.A., *Royal College of Science, Dublin*, **2**, **3**, **12**.

PICHLER, S. F., 162, *Great Portland Street, London*, **6**, **12**.

PILLISCHER, M., 88, *New Bond Street, London*, **14**, **18**.

POOLE, J., & Co., 33, *Spencer Street, Clerkenwell, London*, **3**.

PORTER, H., 181, *Strand, London*, **2**, **14**, **15**.

POSTMASTER-GENERAL, H.M., *St. Martin's-le-Grand, London*, **10**.

PREECE, W. H., *General Post Office, London*, **10**.

PRESTWICH, PROF. J., F.R.S., *Oxford*, **16**.

PRICE, W., 181, *Burrage Road, Plumstead*, **13**.

PRITCHARD, URBAN, M.D., 41, *Guilford Street, Russell Square, London*, **18**.

PROSSER, W. H., 108, *South Hill Park, Hampstead*, **1**, **12**.

RANSOMES, SIMS, & HEAD, *Orwell Works, Ipswich*, **12**.

RAYLEIGH, LORD, F.R.S., 4, *Carlton Gardens, London*, **5**, **6**, **7**.

RAYNOR, W., *Radcliffe, Manchester*, **10**.

READ, MRS., 27, *Sussex Place, South Kensington, London*, **6**.

REID, J., & Co., *Port Glasgow*, **12**.

REID BROTHERS, 12, *Wharf Road, City Road, London*, **10**.

Reynolds, Prof. O., *Owens College, Manchester*, **2**, **3**.
Richardson, Duck, & Co., *Stockton-on-Tees*, **12**.
Ritchie, J., & Son, 25, *Leith Street, Edinburgh*, **11**.
Roberts, W. H., *Snodland, Kent*, **15**.
Roberts, W. Chandler, F.R.S., *Royal Mint, London*, **7**, **13**.
Roberts, Dale, & Co., *Manchester and Warrington*, **13**.
Rolleston, Prof., F.R.S., *Oxford University Museum*, **18**.
Roscoe, Prof., F.R.S., *Owens College, Manchester*, **7**, **13**, **14**.
Ross and Co., 7, *Wigmore Street, Cavendish Square, London*, **7**, **18**.
Rosse, Earl of, F.R.S., *Birr Castle, Parsonstown, Ireland*, **11**.
Round, J., 196, *Camberwell Road, London*, **10**.
Rowley, W., C.E., F.G.S., 74, *Albion Street, Leeds*, **16**.
Royal Agricultural Society of England, 12, *Hanover Square, London*, **12**.
Royal Astronomical Society, *Burlington House, Piccadilly, London*, **11**.
Royal College of Science for Ireland, *Stephen's Green, Dublin*, **1**, **12**. *See also* Professors Adams, Barrett, Galloway, Hennessy, Hull, McNab, O'Reilly, and Pigot.
Royal College of Surgeons of England, *Lincoln's Inn Fields, London*, **18**.
Royal Geographical Society of London, 1, *Savile Row, Burlington Gardens, London*, **15**.
Royal Institution of Great Britain, 21, *Albemarle Street, London*, **8**, **9**, **10**, **12**, **13**, **16**.
Royal Microscopical Society, *King's College, London*, **12**, **18**.
Royal Museum, Salford, *Peel Park, Salford*, **1**, **3**, **7**, **9**, **11**, **12**, **14**, **18**.
Royal Naval Museum, *Greenwich, London*, **3**, **11**, **12**, **15**.
Royal School of Mines, *Jermyn Street, London*, **3**, **12**.
Royal Society, *Burlington House, Piccadilly, London*, **3**, **5**, **9**, **11**, **15**, **16**.
Royal United Service Institution, *Whitehall Yard, London*, **3**, **11**.
Roydon, W., *Liverpool*, **12**.
Royston-Pigott, G. W., M.D., F.R.S., *Hartley Court, Reading*, **3**, **18**.
Rücker, Prof. A. W., M.A., *Yorkshire College of Science, Leeds*, **3**.
Ruhmkorff, 11, *Beak Street, Regent Street*, **10**.
Rutherford, Prof., *Edinburgh*, **18**.
Rutley, F., *Geological Survey Office, Jermyn Street, London*, **16**.
Rutter, J. O. N., F.R.A.S., *Black Rock, Brighton*, **9**.
Sabine, R., 25, *Cumberland Terrace, Regent's Park, London*, **6**, **7**, **10**.
Salford Royal Museum, *Peel Park, Salford*, **1**, **3**, **7**, **9**, **11**, **12**, **14**, **18**.
Samuelson, B., M.P., *Middlesborough*, **13**.
Sanderson and Proctor, *Shore Works, Huddersfield, and* 19 *and* 21, *Queen Victoria Street, London*, **8**, **10**.
Schorlemmer, C., F.R.S., *Owens College, Manchester*, **13**.
Scotland, Geological Survey of, *Edinburgh*, **16**.
Scott, M., 9, *Great Queen Street, Westminster*, **12**.
Scott, R. H., F.R.S., *Director, Meteorological Office*, 116, *Victoria Street, Westminster*, **14**.
Scottish Meteorological Society, *General Post Office Buildings, Edinburgh*, **7**, **14**.
Secretary of State for India, *India Office, Whitehall, London*, **15**.
Shand, Mason, & Co., 75, *Upper Ground Street, London*, **12**.
Sharman, G., *St. Leonard's Villa, West End Lane, Kilburn, London*, **16**.
Siebe and Gorman, *Mason Street, Westminster Bridge Road*, **12**.
Siemens, Dr. C. W., *London*, **3**, **8**.
Simey, A., & Co., *Sunderland*, **12**.
Sinclair, J., 104, *Leadenhall Street, London*, **12**.
Skertchly, Sydney B. J., F.G.S., *Geological Survey, Jermyn Street, London*, **14**.
Skinner, *Sunderland*, **12**.
Smith, Edwin, *Bath*, **11**.

SMITH, T. AND W., *Newcastle-on-Tyne*, **12**.

SMITH, W., C.E., *Newcastle-on-Tyne*, **12**.

SMYTH, J., JUN., M.I.C.E.I., *Milltown, Banbridge, Ireland*, **13**, **14**.

SMYTH, PROF. PIAZZI, *Royal Observatory, Edinburgh*, **3**, **7**, **8**.

SOMERVILLE, J., 20, *Westland Row, Dublin*, **12**.

SORBY, H. C., F.R.S., *Broomfield, Sheffield*, **16**, **18**.

SOUTH KENSINGTON MUSEUM, *London*, **2**, **6**, **7**, **10**, **12**.

SPEECHLY, H., 43, *King's Road, St. Pancras, London*, **6**.

SPENCE, P., *Pendleton Alum Works, Manchester*, **13**.

SPILLER, J., F.C.S., 2, *St. Mary's Road, Canonbury, London*, **7**.

SPOTTISWOODE, W., F.R.S., 50, *Grosvenor Place, London*, **7**.

SPOTTISWOODE, MRS. W., 50, *Grosvenor Place, London*, **7**.

SPRAGUE, J. T., 315, *Green Lane, Birmingham*, **10**.

SPRENGEL, H., 44, *Charlwood Street, Pimlico, London*, **5**, **13**.

STANDARDS DEPARTMENT, BOARD OF TRADE (H. W. Chisholm, Warden), 7, *Old Palace Yard, London*, **3**.

STANFORD, E., *Charing Cross, London*, **16**.

STANLEY, W. F., 3, *Great Turnstile, Holborn, London*, **2**.

STAVERS, G., *Morpeth, Northumberland*, **12**.

STEPHENSON, J. W., *Equitable Assurance Office, Mansion House Street, London*, **18**.

STEVENSON, D. & T., *Northern Lighthouse Office, Edinburgh*, **12**.

STEWART, PROF. BALFOUR, F.R.S., *Owens College, Manchester*, **8**.

STIFF AND SONS, *London Pottery, Lambeth*, **13**.

STIRLING, THE BURGH OF, *Stirling*, **3**.

STONE, DR. W. H., *Dean's Yard, Westminster*, **4**, **6**, **7**, **9**, **11**, **17**, **18**.

STRUTHERS, PROF., *Aberdeen University*, **18**.

SUB-WEALDEN EXPLORATION COMMITTEE (W. Topley, F.G.S., and H. Willett, F.G.S.), **16**.

SUGG, W., *Vincent Works, Vincent Street, Westminster*, **7**.

SULLIVAN & CO., *British Alkali Works, Widnes, Lancashire*, **13**.

SUNDERLAND, CORPORATION OF, **12**.

SWIFT, J., 43, *University Street, Tottenham Court Road, London*, **18**.

SYMONS, G. J., 62, *Camden Square, London*, **9**, **14**, **15**.

TAIT, PROF. P. G., M.A., *University of Edinburgh*, **8**, **10**.

TALBOT, H. FOX, F.R.S., *Lacock Abbey, Chippenham*, **7**.

TANGYE BROTHERS, AND HOLMAN, 10, *Laurence Pountney Lane, London*, **12**.

TAYLOR, MAJOR M. L., R.A., *Royal Artillery Institution, Woolwich*, **3**, **15**.

THAMES IRON WORKS AND SHIPBUILDING CO., *Orchard Yard, Blackwall*, **12**.

THAMES IRON WORKS CO., *Millwall*, **12**.

THERMO-ELECTRIC GENERATOR CO., 27, *New Street, Cloth Fair, London*, **10**.

THOMAS, J. W., *The Laboratory, Cardiff, Wales*, **12**.

THOMSON, PROF. SIR W., F.R.S., *The University, Glasgow*, **1**, **3**, **4**, **10**, **12**, **15**.

THOMPSON, J. L., AND SONS, *Sunderland*, **12**.

THOMPSON, R., Junr., *Sunderland*, **12**.

THORPE, PROF., *Leeds*, **7**, **13**.

THWAITES AND CARBUTT, *Bradford, Yorkshire*, **12**, **13**.

TISLEY AND SPILLER, 172, *Brompton Road, London*, **4**, **10**, **14**.

TOPLEY, W., F.G.S., *Geological Survey, Jermyn Street, London*, **16**.

TRIBE, A., 17, *Pembridge Square, London*, **13**.

TRINITY COLLEGE, DUBLIN, *Dublin*. (*See* JELLETT AND LLOYD.)

TRINITY HOUSE, LONDON, CORPORATION OF, *Trinity Square, Tower Hill, London*, **12**.

TROUGHTON AND SIMMS, 138, *Fleet Street, London*, **3**, **11**, **15**.

TYLER HAYWARD & CO., 84, *Upper Whitecross Street, London*, **12**.

TYLOR, J., AND SONS, 2, *Newgate Street, E.C.*, **3**, **12**.

TYNDALL, PROF., F.R.S., 21, *Albemarle Street, London*, **6**, **8**, **9**.

UNITED SERVICE INSTITUTION, ROYAL, *Whitehall Yard, London*, **3**, **11**.

University of Edinburgh, *Edinburgh*, **8, 9, 10, 11, 12, 14**.
University of Oxford Museum, *Oxford*, **16, 18**.
Unwin, Prof. W. C., *Cooper's Hill College, Staines*, **3**.
Varley, S. A., *Hatfield, Herts*, **10**.
Wallace, J. (Tangye Brothers & Rake), 3, *St. Nicholas Buildings, Newcastle-upon-Tyne*, **13**.
Walter, J., M.P., 40, *Upper Grosvenor Street, London*, **12**.
War Office, *Pall Mall, London*, **3, 10**.
Ward, J. Clifton, *Greta Bank Cottage, Keswick*, **16**.
Ward, W. S., *Denison Hall, Leeds*, **5, 10, 13, 15, 18**.
Warden, Muirhead, and Clark, 29, *Regent Street, Westminster, London*, **10**.
Warwick, T. A., *Derby*, **10**.
Waterhouse, A., 20, *New Cavendish Street, London*, **21**.
Watkin, Lieut. H., R.A., 1, *Uxbridge Villa, Paget Road, Shooters Hill, London*, **3**.
Watson and Son, 313, *High Holborn, London*, **11, 15**.
Wear, Commissioners of the River, *Sunderland*, **12**.
Webb, F. W., *Locomotive Department, L. and N. W. Railway, Crewe*, **12**.
Wedekind, H., 4, *Great Tower Street, London*, **13**.
Wheatstone Collection of Physical Apparatus, *King's College, London*, **4, 7, 9, 10, 11**.
Wheeler, E., 48, *Tollington Road, Holloway, London*, **18**.
White, J., 241, *Sauchiehall Street, Glasgow*, **10**.
White, J., *Cowes, Isle of Wight*, **12**.
Whitwell, T., *Stockton-on-Tees*, **13**.
Whitworth, Sir Joseph, F.R.S., & Co., 44, *Chorlton Street, Manchester*, **3, 13**.
Widnes Metal Co., *West Bank, Widnes, Lancashire*, **13**.
Willett, H., F.G.S., *Arnold House, Brighton*, **16**.
Williams, J., F.C.S., 16, *Cross Street, Hatton Garden, London*, **8**.
Willis, W., 49, *Palace Grove, Bromley, Kent*, **7**.
Willis, W., Junr., 73, *Monument Lane, Edgbaston, Birmingham*, **7**.
Wiltshire, Rev. T., M.A., *Secretary, Geological Society, Burlington House, Piccadilly, London*, **16**.
Winchester, Corporation of, *Winchester*, **3**.
Wollaston, G. H., 117, *Pembroke Road, Clifton, Bristol*, **6, 7, 13, 17**.
Wood, G. S., 20, *Lord Street, Liverpool*, **18**.
Wood, J., *Ivy Cottage, Burnley Lane*, **12**.
Woodbury Permanent Photographic Printing Co., 157, *Great Portland Street, London*, **7**.
Woodcroft, Bennet, F.R.S., *Great Seal Patent Office, London*, **1, 2, 3, 9, 12**.
Woodward, C. J., *Birmingham and Midland Institute, Birmingham*, **4, 7**.
Works, H.M. Office of, *London*, **1, 18**.
Wornum and Sons, 16, *Store Street, London*, **6**.
Wortley, Col. Stuart, *Patent Museum, South Kensington, London*, **7**.
Wrightson, T., *Sunderland*, **12**.
Yeates and Son, 2, *Grafton Street, Dublin*, **6, 7, 8, 10, 11, 14**.
Young, J., *West Docks, South Shields*, **12**.
Yorkshire College of Science, Council of, *Leeds*, **1, 3, 4, 13**.
Yorkshire Philosophical Society, Council of, *York*, **11**.
Zanni, G., 31, *Compton Road, Highbury, and* 1, *James Street, Old Street, City Road, London*, **10**.
Zoological Society of London, 11, *Hanover Square, London*, **18**.

AUSTRO-HUNGARIAN EMPIRE.

Arzberger, Prof. F., *Imp. & Royal Technical High School, Brünn*, **13, 15**.
Bauer, Prof. Dr. A., *Polytechnic Institute*, 20, *Kamtnerstrasse, Vienna*, **8, 13**.

BELGIUM.

Bruylants, G., *Laboratory of General Chemistry, University of Louvain*, **13**.

Cougnet, J., *Ixelles, Brussels*, **5**.

Gérard, A. J., 5, *Place St. Lambert, Liège*, **3**.

Gochet, Prof. A. M., *Normal School, Carlsbourg, Luxembourg*, **15, 19**.

Henry, L., *Professor of Chemistry, University of Louvain*, **13**.

Le Boulengé, Major, 23, *Thier de la Fontaine, Liège*, **3**.

Leurs, Lieut.-General, 9, *Rue de la Longue-haie, Brussels*, **3**.

Malaise, Prof. C., Member of the Royal Academy of Belgium, *State Agricultural Institute, Gembloux, Province of Namur*, **16**.

Martinot, A., *Nismes, Mariembourg*, **19**.

Navez, Lieut. Col., *Schaerbeeth, Brussels*.

Piron, Frère M., *Director of the Normal School, Carlsbourg*, **1, 2**.

Renard, A., 11, *Rue des Récollets, Louvain*, **16**.

Sacré, E., 30, *Rue Cantersteen, Brussels*, **3**.

Schwann, Prof. T., 11, *Quai de l'Université, Liège*, **7, 18**.

Simonan and Toovey, *Brussels*, **7**.

Van Rysselberghe, F., *Paymaster, Royal Navy, Antwerp, late Professor at the School of Navigation, Ostend*, **3, 14**.

Van Scherpenzeel Thini, J., *Director of Mines*, 34, *Rue Nysten, Liège*, **16**.

FRANCE.

Alvergniat Frères, 10, *Rue de la Sorbonne, Paris*, **10**.

Auzoux, Dr., 96, *Rue de Vaugirard, Paris*, **18**.

Baudin, 276, *Rue St. Jacques, Paris*, **5, 14**.

Becquerel, M. E., *Paris*, **11**.

Biard, *Paris*, **15**.

Bonis, Madame, *Paris*, **10**.

Bontemps, *Telegraph Inspector, Paris*, **10**.

Bourdon, *Paris*, **3, 4, 5, 12**.

Bourgogne, E., 34, *Rue Cardinal Lemoine, Paris*, **18**.

Bréguet, 81, *Boulevard Mont Parnasse, Paris*, **5, 9, 10, 11, 13, 16**.

Cacheleux, 6, *Rue des Vieilles Haudriettes, Paris*, **12**.

Carré, E., *Paris*, **5, 10**.

Chameroy, 162, *Faubourg St. Martin, Paris*, **3**.

Cleuet, *Paris*, **12**.

College of France, Paris, **4, 6, 7, 8, 10, 18**.

Collin & Co., 6, *Rue de l'Ecole de Médecine, Paris*, **18**.

Conservatoire des Arts et Métiers, *Paris*, **1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 14, 17**.

Crétès, 66, *Rue de Rennes, Paris*, **7, 18**.

Daubrée, Membre de l'Institut, *Director of the School of Mines, Paris*, **16**.

D'Abbordre, 120, *Rue du Buc, Paris*, **15**.

Delegrave, M., *Paris*, **15**.

Delesse, *Chief Engineer of Mines, Paris*, **15, 16**.

Deleuil, 42, *Rue des Fourneaux, Paris*, **3, 13**.

Department of Lighthouses, *France*, **12**.

Depôt of Marine Charts and Plans, *Paris*, **15**.

Desains, Membre de l'Institut, 78, *Rue d'Arras, Paris*, **18**.

Deschiens, *Paris*, **10**.

Digeon, 13, *Rue de Marseille, Paris*, **3, 4, 12**.

Dolfus, E., *Paris*, **12**.

Duboscq, J., 21, *Rue de l'Odéon, Paris*, **6, 7, 10, 11**.

Dujardin, *Paris*, **7**.

Dumoulin-Froment, 85, *Rue Notre Dame des Champs, Paris*, **2, 3, 9, 10, 15**.

Dumas, J., *Paris*, **13**.

Eastern Railway of France, *Paris*, **3**.

École de Pharmacie, *Rue de l'Arbalète, Paris*, **7**.

École Polytechnique, *Paris*, **3, 5, 6, 7, 8, 9, 10.**
Enfer Fils, 10, *Rue de Rambouillet, Paris*, **13.**
Engel Dolfus, 9, *Rue St. Fiacre, Paris*, **12.**
Erhard, *Paris*, **7, 10, 15.**
Faculty of Sciences, *Paris*, **5, 8.**
Feil, 56, *Rue Lebrun, Paris*, **7.**
Fizeau, Membre de l'Institut, 3, *Rue de la Vieille Estrapade, Paris*, **7.**
Fontoure, H., 92, *Rue St. Georges, Paris*, **10.**
Fortin Hermann, MM., 122, *Boulevard Mont Parnasse, Paris*, **3.**
French Commission for Observing the Transit of Venus in 1874, **11.**
Gavard, A., 70, *Quai des Orfevres, Paris*, **1, 2.**
Gillot, *Madame, Paris*, **7.**
Girard, A., *Prof., Conservatoire des Arts et Métiers*, 292, *Rue St. Martin, Paris*, **18.**
Goupil & Co., *Paris*, **7.**
Gros, 94, *Rue de Montreuil, Paris*, **12.**
Guéroult, G., 2, *Rue de Vienne, Paris*, **6.**
Guyot D'Arlincourt, 102, *Rue Neuve des Mathurins, Paris*, **10.**
Haincque De St. Senoch, *Paris*, **15.**
Hayaux du Tilly, 15, *Rue de Lisbonne, Paris*, **15.**
Hirn, G. A., 3, *Logelbach, Colmar*, **3.**
Honzeau, M., *Paris*, **13.**
Isoard Fils, 78, *Rue St. Maur, Paris*, **3.**
Jamin, *Paris*, **9.**
Jannettaz, 9, *Rue Linne, Paris*, **8.**
Janssen, Membre de l'Institut, 33, *Rue Labat, Paris*, **11.**
Laboratoire du Collége de France, *Place Cambrai, Paris*, **13.**
Lancelot, *Paris*, **6.**
Larrey, Baron, 91, *Rue de Lille, Paris*, **18.**
Launay, Prof., *Lycée, Caen*, **15.**
Laurent, *Paris*, **7, 8, 18.**
Laussedat, Col., Prof., Conservatoire des Arts et Métiers, *Paris*, **15.**
Lemaire Douchy, 64, *Rue Taitbout, Paris*, **16.**
Letellier, **19.**
Loiseau Fils, 29, *Rue Richelieu, Paris*, **5, 9, 10.**
Luizard, 43, *Rue St. André des Arts, Paris*, **5, 7, 8, 10.**
Lutz, *Paris*, **3, 7, 11, 17, 18.**
Malligand Fils, 1, *Boulevard St. Michel, Paris*, **13.**
Mannheim, Prof., *Ecole Polytechnique, Paris*, **1.**
Mariais, 260, *Rue St. Honoré, Paris*, **10.**
Marey, Prof. (*Collegé of France*), 13, *Rue Dugay Trouin, Paris*, **18.**
Mascart, Prof. (*College of France*), *Paris*, **7.**
Mathieu, *Paris*, **18.**
Molteni, T. and A., 44, *Rue du Chateau d'Eau, Paris*, **2, 7, 11, 15.**
Mouret, 8, *Cour des Petites Ecuriés* (*Redier*), *Paris.*
Nachet, A., 17, *Rue St. Séverin, Paris*, **7, 18.**
Navez, *Paris*, **3.**
Observatory of Paris, **7, 11.**
Orsat, *Paris*, **13.**
Paris, Vice-Admiral, *President de l'Academie des Sciences, Paris*, **12.**
Phares de France, Service des, *Place du Trocadéro, Paris*, **12.**
Photographic Society, *Paris*, **7.**
Picart, A., 20, *Rue Mayet, Paris*, **18.**
Polytechnic School, *Paris*, **3, 5, 6, 7, 8, 9, 10.**
Redier, *Paris*, **3, 10, 14.**
Renaud Tachet, MM., 17, *Rue Richelieu, Paris*, **1, 2.**
Richard, *Paris*, **14.**
Roulot, *Paris*, **18.**
Ruhmkorff, 15, *Rue Champollion, Paris*, **8, 10.**
School of Pharmacy, *Paris*, **7.**
Sciences, Faculté des, *Paris*, **5, 8.**
Seguier, M. le, 3, *Rue du Régard, Paris*, **12.**
Service des Phares de France (Lighthouse Service of France), *Place du Trocadéro, Paris*, **12.**
Société de l'Alliance, La, 25, *Rue Dufrenoy, Paris*, **10.**
Société des Voyages d'Études autour du Monde, 10, *Rue du Mont Thabor, Paris*, **15.**
Société Française de Photographie, 20, *Rue Louis le Grand, Paris*, **7.**
Tavernier Gravet, *Paris*, **1, 3, 15.**
Telegraph Department, *Paris*, **10.**

THIEL, *Paris*, **7**.
TONDOLA & CO., *Paris*, **3**.
TRAMONT, 9, *Rue de l'École de Médecine, Paris*, **18**.
TRESCA, H. E., *Membre de l'Académie des Sciences, Sous-Directeur du Conservatoire des Arts et Métiers, Paris.*
TROUVÉ, G., 6, *Rue Thérèse, Paris*, **10, 18**.
VIDAL, L., 13, *Quai Voltaire, Paris*, **7**.
VILLARCEAU, I., *Membre de l'Institut*, 18, *Avenue de l'Observatoire, Paris*, **3**.
WENTZEL, MADAME, 6, *Rue Bretonviller, Paris*, **2**.
WERLEIN, *Paris*, **2, 17, 18**.
WIESNEGG, 64, *Rue Gay Lussac, Paris*, **13**.
WINNEREL, 35, *Galerie Montpensier (Gabriel), Paris*, **3**.

GERMANY.

ACADEMY OF MINES, ROYAL (Prof. Hauchecorne, Director), *Berlin*, **12, 16**.
ACADEMY OF MINES, ROYAL (Prof. Richter, Director), *Freiberg, Saxony*, **10, 12, 13, 16, 17**.
ADMIRALTY, IMPERIAL, HYDROGRAPHIC DEPARTMENT AND NAUTICAL OBSERVATORY, *Berlin and Hamburg*, **8, 9, 14, 15**.
ALBERT, J. W., 34, *Neue Mainzerstrasse, Frankfort-on-Maine*, **6, 7**.
ALBRECHT, *Tübingen*, **6, 17**.
ALTHAUS, E., *Superintendent of Mines, Breslau*, **8**.
APEL, W., *Göttingen*, **7, 14, 17**.
APPUUN, G., AND SONS, *Hanau*, **6**.
ASSOCIATION FOR THE MANUFACTURE OF ANILINE, *Berlin*, **13**.
AUGUST, DR. F., *Humboldt-Gymnasium, Berlin*, **11**.
BABO, PROF. von (Chemical Laboratory), *Freiburg, Breisgau*, **6**.
BACH, DR. O., *Leipzig*, **13**.
BAEYER, LIEUT.-GENERAL (President of the Geodetic Institute), *Berlin*, **3, 15**.
BALL, *Freiburg, Breisgau*, **13**.
BAMBERG, C., 158, *Linienstrasse, Berlin*, **3, 9, 11, 14, 15**.
BAU-DEPUTATION, *Hamburg*, **15**.
BAUER, PROF. DR. A., *Polytechnic Institute, Vienna*, **8**.
BAUERNFEIND, PROF. DR. von (Geodetic Institute, Royal Polytechnic School), *Munich*, **15**.
BAUR AND HAEBE, *Stuttgart*, **10, 14**.
BECKER, AUG. (DR. MEYERSTEIN'S Workshops), *Göttingen*, **7, 18**.
BEETZ, PROF. DR. (Polytechnic School), *Munich*, **3, 8, 10, 18**.
BERGGEWERKSCHAFTSKASSE (Dr. Heintzmann), *Bochum*, **3, 11, 12, 13, 16, 19**.
BERLIN, PHYSICAL INSTITUTION OF (Dr. Helmholtz), **9**.
BERNSTEIN, A., AND CO., 50, *Markgrafen Strasse, Berlin*, **3**.
BERNSTEIN, PROF. (Director), *Physiological Institute, University of Halle*, **3**.
BEZOLD, PROF. W. von (Polytechnic School), *Munich*, **3, 7, 10**.
BIEDERMANN, DR. R., *Berlin*, **13**.
BLATTNER, C. (Polytechnic School), *Munich*, **7**.
BLATZBECKER, DR. A. A., *Cologne*, **13**.
BOCK AND HANDRIK, 2, *Falkenstrasse, Dresden*, **2, 12**.
BOHN, PROF. DR., *Aschaffenburg*, **5, 14**.
BONSACK, A., *Berlin*, **3, 15**.
BORCHARDT, PROF., *Berlin*, **2**.
BORCHARDT, E., 37, *Heinrichstrasse, Hanover*, **10**.
BRAUN, DR. O., *Berlin*, **12**.
BREITHAUPT, J. W., AND SON, *Cassel*, **3, 11, 15, 16, 17**.
BRENDEL, R., *Kurfürstendamm, Berlin*, **18**.
BRESLAU COMMITTEE FOR THE SCIENTIFIC APPARATUS EXHIBITION, LONDON, *Breslau*, **2, 3, 8, 11, 13, 14, 18**.
BRILL, PROF. DR. (Polytechnic School), *Munich*, **2**.
BROCKING, W., *Hamburg*, **3**.
BRUHNS, PROF. DR., *Leipzig*, **11**.
BÜCHLER, J. H., *Breslau*, **13**.
BUFF, PROF. DR., *Giessen*, **3, 4, 7, 10**
BUNGE, P., *Hamburg*, **3**.
CARL AND HOMANN, *Nuremberg*, **15**.

Gümbel, Dr. (Geognostic Survey of Bavaria), **16**.
Haak, W., *Neuhaus, Thüringen*, **8**, **14**, **15**.
Haedicke, G., *Demmin*, **3**, **4**, **5**, **15**.
Hahn, A. & R., *Cassel*, **3**, **15**, **16**.
Halle, Industrial School (*Dr. Kohlmann*), **3**, **4**, **12**.
Halle, Town School (Meyer), **3**.
Halle, University of, **3**, **4**.
Haarmann, Dr. W., *Holminden*, **13**.
Hartnack, Dr. E., *Potsdam*, **18**.
Hauchecorne, Prof. (Director, Royal Geological Institute and Mining Academy), *Berlin*, **12**, **16**.
Heintz, Prof. Dr., *Halle*, **13**.
Heinzerling, Prof. Dr. (Polytechnic School), *Aix-la-Chapelle*, **12**.
Heis, Prof. Dr. E., *Münster*, **2**, **9**, **11**.
Heller, F., *Nuremberg*.
Helmert, Prof. Dr. (Polytechnic School), *Aix-la-Chapelle*, **15**.
Helmholtz, Prof. Dr., *Berlin*, **9**, **10**.
Henneberg, Prof. Dr., *Göttingen*, **18**.
Hensen, Prof. Dr., *Kiel*, **18**.
Herbst, A., 26a, *Krautstrasse, Berlin*, **7**, **10**, **11**, **13**.
Hermann, Prof. G. (Polytechnic School), *Aix-la-Chapelle*, **1**.
Heustreu, *Kiel*, **11**.
Himly, Prof. Dr., *Kiel*, **8**.
Hirschberg, F., 9, *Weidenstrasse, Breslau*, **6**.
Hittorf, Prof. Dr., *Münster*, **10**, **13**.
Hofmann, Prof. Dr. A. W., *Berlin*, **13**, **19**.
Honigmann, M., *Aix-la-Chapelle*, **31**.
Hornung, F., *Langenbeutingen*, **11**.
Hübner, Prof. Dr., *Göttingen*, **13**.
Hugershoff, F., *Leipzig*, **13**, **19**.
Hulwa, Prof. Dr., *Breslau*, **13**.
Hutstein, J., *Breslau*, **13**.
Industry, High School of, *Cassel*, **2**, **3**, **9**, **15**, **16**, **17**, **18**.
Industrial School (Dr. Kohlmann, Director), *Halle*, **3**, **4**, **12**.
Institute of Physics (Prof. Dr. A. Claus), *University of Freiburg, Breisgau*, **19**.
Institute of Physics (Prof. Karsten, Director), *University of Kiel*, **3**, **18**.
Intze, Prof. O. (Polytechnic School), *Aix-la-Chapelle*, **3**, **4**.
Jacobsen, Prof. Dr., *Rostock*, **13**.
Jessen, Prof. Dr., *Eldena, Pomerania*, **18**.
Jobst, F., *Stuttgart*, **13**.
Jolly, Prof. Dr. von, *Munich*, **3**, **5**, **8**, **13**.
Jung, Ch., *Giessen*.
Jung, R., *Heidelberg*, **7**, **10**, **18**.
Kahlbaum, C. A. F., *Berlin*, **13**.
Karsten, Prof. Dr., *Kiel*, **3**, **18**.
Karsten, Prof. Dr., *Rostock*, **7**, **15**.
Kaufmann, K. J., *Königsberg, Prussia*, **13**.
Keiser & Schmidt, 14, *Johannis Strasse, Berlin*, **7**, **10**.
Kiel, Physical Institute of the University of, **3**, **18**.
Kleemann, *Halle*, **3**.
Klinkerfues, Prof. Dr., *Göttingen*, **3**, **14**.
Knoblauch, Prof. Dr., *Halle*, **3**, **4**.
Knoblich, T., 24, *Amiralität Strasse, Hamburg*, **3**.
Kny, Prof. Dr., *Berlin*, **18**.
Kobell, Prof. Dr. F. von, *Munich*, **7**.
Kohlmann, Dr., *Director, Industrial School, Halle*, **3**, **4**, **12**.
Kramer, C., *Freiburg, Breisgau*, **13**.
Krause, Prof. Dr., *Göttingen*, **18**.
Krebs, Prof. Dr. G., *Frankfort-on-Maine*, **4**.
Kronecker, Prof. Dr., *Leipzig*, **18**.
Krüss, A., *Hamburg*, **7**.
Kuhnemann, Dr. G., *Dresden*, **13**.
Kuhtz & Co., *Brandenburg-on-Havel*, **18**.
Kummer, Prof. Dr. E. E., *Berlin*, **5**.
Kundt, Prof. Dr., *Strasburg*, **7**, **9**.
Landolt, Prof. Dr. (Polytechnic School), *Aix-la-Chapelle*, **13**, **19**.
Landois, Prof. Dr., *Münster*, **18**.
Landsberg & Wolpers, *Hanover*, **1**, **3**, **10**, **19**.
Laqueur, Prof., *Strasburg*, **18**.
Lasaulx, Prof. von, *Breslau*, **13**, **15**, **16**.
Laspeyres, Prof. (Polytechnic School), *Aix-la-Chapelle*.
Leitz, E., *Wetzlar*, **18**.

LENTZ, E. A., 36 & 37, *Spandauer Strasse, Berlin*, **13, 19.**
LENTZ, J., *Berlin*, **19.**
LEPSIUS, PROF. DR., *Berlin*, **5.**
LEYBOLD, E. (Successors to), *Cologne*, **19.**
LIEBERMAN, PROF. C., *Berlin*, **13.**
LINGKE, A., & Co. (M. Hildebrand and E. Schramm), *Freiberg, Saxony*, **11, 15, 16, 17.**
LIST, DR., *Hagen*, **5.**
LISTING, PROF. DR., *Göttingen*, **7.**
LOCHMANN, P., *Zeitz*, **12.**
LÖCKERMANN, DR., *Hamburg*, **11.**
LOHDE, L., *Berlin*, **2.**
LÖHMANN, R., 3, *Brückenstrasse, Berlin*, **3.**
LOHSE, DR., C. (*Astronomer of the Royal Astro-Physical Observatory*), *Potsdam*, **11.**
LOMMEL, PROF. DR. *Erlangen*, **7, 18.**
LUCAE, PROF. A., *Berlin*, **6.**
MAGNUS, DR., *Breslau*, **18.**
MAJER, F., *Strasburg*, **18.**
MARBURG, MATH. AND PHYSICAL INSTITUTE (Prof. Melder), **3.**
MATTHIESSEN, PROF. DR., *Rostock*, **14.**
MEIDINGER, PROF. DR. H., *Carlsruhe*, **8, 10, 12.**
MEISSNER, A. (Müller and Reinecke), *Berlin*, **3, 15.**
MERCK, E., *Darmstadt*, **13.**
MEYER, L., *Berlin*, **8.**
MEYER, PROF. L., *Carlsruhe*, **13.**
MEYER, DR. O. E., *Breslau*, **5.**
MEYER (*Town School*), *Halle*, **3.**
MEYERSTEIN, DR., *Göttingen*, **7, 18.**
MICHAELIS, PROF. A., *Carlsruhe*, **13.**
MINISTERIAL COMMISSION FOR THE SCIENTIFIC EXPLORATION OF THE GERMAN SEAS, *Kiel*, **15.**
MITSCHERLICH, PROF. A., *Münden, Hanover*, **5, 7, 8, 13, 17, 19.**
MITTELSTRASS BROTHERS, *Magdeburg*, **10.**
MÖBIUS, PROF. DR., *Kiel*, **18.**
MÖHL, DR. H. (*Royal High School of Industry*), *Cassel*, **16.**
MÖLLER, L., *Giessen*, **17.**
MÜLLER, DR. F., *Osnabruck*, **14.**
MUNICH, UNIVERSITY OF, **3, 8, 13.**
NARTEN, DR. W. (Royal High School of Industry), *Cassel*, **2.**
NAUTICAL OBSERVATORY-"DEUTSCHE SEEWARTE" (Dr. Neumayer, Director), *Hamburg*, **8, 9, 14, 15.**

NÖRDLINGER, PROF. DR., *Hohenheim*, **3, 18.**
OPPEL, PROF., J. J., *Frankfort-on-Maine*, **2, 6, 7, 11.**
OPPEL, DR. K., **11.**
OPPENHEIM, PROF. A., *Berlin*, **13.**
ORTH, PROF. DR., *Berlin*, **16.**
OSTERLAND, C., *Freiberg, Saxony*, **13, 16.**
OTT & CORADI, *Kempten*, **2, 3, 15.**
PANSCH, DR., *Kiel*, **18.**
PERNET, DR. (Assistant, Cabinet of Physics), *Breslau*, **8.**
PFAFF, PROF. DR., *Erlangen*, **8, 17.**
PHARMACEUTICAL INSTITUTE OF THE UNIVERSITY, *Breslau*, **13.**
PIEL, H., *Bonn*, **17.**
PINNER, DR. A., *Berlin*, **13.**
PINZGER, C. G., *Breslau*, **5.**
POLECK, DR., *Breslau*, **13.**
PRESTEL, PROF., *Emden*, **1, 11, 14, 17.**
PRUGGER, *Buttermelcher Strasse, Munich*, **19.**
RAMMÉ AND SODTMANN, *Hamburg*, **18.**
RAPHAEL, M., *Breslau*, **2, 3, 7, 10, 13, 15, 17, 18.**
RATH, PROF. DR. G. vom, *Bonn*, **17.**
RECKE, H., *Freiburg, Saxony*, **14.**
RECKLINGHAUSEN, PROF. DR., *Strasburg*, **18.**
RECKNAGEL, DR. (Royal School of Industry), *Kaiserslautern*, **5, 14.**
REIMER, D. (Reimer and Hoefer), *Berlin*, **11, 15.**
REPSOLD & SONS, *Hamburg*, **11, 15.**
REULEAUX, PROF. (Director of the Royal Polytechnic Academy), *Berlin*, **1, 3, 4, 11.**
RHENANIA COMPANY, *Stolberg, Aix-la-Chapelle*, **13.**
RICHTER, E. G., & Co., *Chemnitz, Saxony*, **2.**
RIECKE, PROF. DR., *University of Göttingen*, **9, 10.**
RODIG, C., *Hamburg*, **18.**
ROHRBECK, LUHME, & Co., *Berlin*, **4, 19.**
ROSE, PROF., *Strasburg*, **13.**
ROSENTHAL, PROF. DR., *Erlangen*, **18.**
ROYAL ACADEMY OF MINES (Prof. Hauchecorne, Director), *Berlin*, **12, 16.**

Royal High School of Industry (Dr. Wiecke, Director), *Cassel*, **2, 3, 9, 15, 16, 17, 18.**
Royal Library (Prof. Dr. Lepsius, Chief Librarian), *Berlin*, **5.**
Royal Mining Directory, *Saarbrück*, **16.**
Royal Museum (Dr. Pinder, Director), *Cassel*, **3, 5, 11, 12, 18.**
Royal Polytechnic (Gewerbe) Academy (Prof. F. Reuleaux, Director), *Berlin*, **1, 3, 4, 11.**
Royal Polytechnic School, *Aix-la-Chapelle*, **3, 4.**
Royal Prussian General Staff, Ordnance Survey (Lieut.-General von Morozowitsch), *Berlin*, **15.**
Royal Prussian Geodetic Institute, *Berlin*, **3.**
Royal Prussian Upper Mining Court, *Breslau*, **16, 19.**
Royal Saxon Mining Academy (Prof. Richter, Director), *Freiberg*, **10, 12, 13, 16, 17.**
Rumann, C., *Göttingen*, **18.**

Saamè & Co., *Ludwigshafen-am-Rhein*, **13.**
Sartorius, F., *Göttingen*, **3, 5, 13.**
Schäffer, H., *Darmstadt*, **3.**
Scheibler, Dr. C., *Berlin*, **13.**
Schering, Prof. Dr., *Göttingen*, **9, 11, 15.**
Schering, E., *Berlin*, **13.**
Schickert, H., *Dresden*, **3.**
Schmidt and Haensch, 2, *Neue Schönhauser Strasse, Berlin*, **7, 11, 13, 15, 18.**
Schober, J., 35, *Adalbert Strasse, Berlin*, **13, 19.**
Schotte, E., *Potsdamer Strasse, Berlin*, **11, 15.**
Schreiber, Dr., *Chemnitz*, **14.**
Schröder, H., *Hamburg*, **11.**
Schubring, G., *Erfurt*, **6, 11.**
Schuchardt, Dr. T., *Görlitz*, **7, 13, 17.**
Schur, Dr. (Assistant, Observatory), *Strasburg*, **11.**
Schütte, O., *Cologne*, **8.**
Schwerd, L. E., *Carlsruhe*, **10.**
Seibert and Krafft, *Wetzlar*, **18.**
Seidel, Prof. (Conservatorium of the Mathematical and Physical Collections of Bavaria), *Munich*, **11.**
Siemens, Dr. W., *Berlin*, **10.**
Siemens Bros. & Co., *Charlottenburg, Berlin*, **5, 10, 12.**
Siemens and Halske, *Markgrafen Strasse, Berlin*, **3, 5, 7, 10, 14.**
Sievers, F., *Wehlheiden, Cassel*, **16.**
Sitte, R., *Breslau*, **18.**
Society, German Chemical, **13.**
Sohncke, Prof., *Carlsruhe*, **17.**
Sommerbrodt, Dr., *Breslau*, **18.**
Sömmering, C., *Frankfort-on-Maine*, **10.**
Spiegel, M., *Breslau*, **16.**
Sprenger, E., 75, *Ritterstrasse, Berlin*, **3, 15.**
Staudinger & Co. (F. W. von Gehren), *Giessen*, **3, 5.**
Steeg, W., *Homburg*, **8, 17.**
Steger, A., *Kiel*, **3, 8, 15.**
Steger & Honikel, *Leipzig*, **18.**
Stein, Dr. S. T., *Frankfort-on-Maine*, **18.**
Steinheil, A. & E., *Munich*, **11.**
Steinheil, C. A. Sons, *Munich*, **11.**
Stern, H., *Oberstein*, **3.**
Stöhrer, E., *Leipzig*, **9, 10, 18, 19.**
Stollenreuther, *Munich*, **18.**
Stürtz, B., *Bonn*, **16, 17.**
Strasburg, Chemical Institute of the University of, **13, 19.**
Süss, F., *Marburg*, **6, 7, 18.**
Talbot, R., 68, *Auguststrasse, Berlin*, **7.**
Tasché, Dr., *Giessen*, **10.**
Telegraphic Department, Imperial German, *Berlin*, **10.**
Teller, Jul., *Munich*, **10.**
Teschner, W. (Successor to J. Amuel), 180, *Friedrichstrasse, Berlin*, **18.**
Tollens, Prof. B., *Göttingen*, **13.**
Tieftrunk, Dr., *Municipal Gasworks, Berlin*, **13.**
Tiemank, Dr. F., *Berlin*, **13.**
Toninetti, P. (Pathological Institution, Prof. Dr. Virchow, Director), *Berlin*, **18.**
Trommsdorff, Dr. H., *Erfurt*, **13.**
Trunk, C., *Eisenach*, **11.**
Uhlenhuth, E., *Anclam, Pomerania*, **2, 15.**
Urach, H. H. The Duchess of, *Stuttgart*, **1.**
Vaast and Littmann, *Halle*, **8.**
Vetter C. (formerly L. Hestermann), *Hamburg*, **19.**
Vierordt, Prof. Dr. von, *Tubingen*, **18.**

VIRCHOW, PROF. DR. (Pathological Institute), *Berlin*, **18**.
VOGEL, DR. H. C. (Astronomer of the Royal Astro-Physical Observatory), *Potsdam*, **11**.
VOGEL, PROF. DR. H. W., *Berlin*, **11**.
VOIGT, G. (Voigt & Hochgesang), *Göttingen*, **3**, **16**, **18**.
VOIGTLANDER AND SON (Chevalier von Voigtländer), *Brunswick*, **7**.
VORSTER AND GRUNEBERG, *Kalk, Cologne*, **13**.
VOSS, R., *Berlin*, **9**, **10**.
WAIBLER, L., *Darmstadt*, **10**.
WALDENBURG, PROF. DR., *Berlin*, **5**, **18**.
WANNSCHAFF, J., 63, *Grossbeeren Strasse, Berlin*, **15**.
WARMBRUNN, QUILITZ, & CO., 40, *Rosenthaler Strasse, Berlin*, **5**, **7**, **8**, **9**, **10**, **13**, **14**, **18**, **19**.
WASSERLEIN, R., 34, *Bernburger Strasse, Berlin*, **18**.
WEBER, DR. A., *Darmstadt*, **18**.
WEBER, PROF. DR. H. (Collegium Carolinum), *Brunswick*, **5**.
WEBER, PROF. R. (Academy of Forestry), *Aschaffenburg*, **1**.
WEBER, A., *Würzburg*, **5**, **18**.
WEBER, CH., *Eisenach*, **16**.
WEINHOLD, PROF., *Chemnitz*, **7**.
WEINZIERL, J., *Glogau, Silesia*, **13**.
WESSELHÖFT, *Halle*, **8**.
WESTPHAL, G., *Celle, Hanover*, **3**.
WICHELHAUS, PROF., *Berlin*, **13**.
WICHMANN, A., 17, *Johannis Strasse, Hamburg*, **18**.
WIECKE, DR., *Cassel*, **2**.
WIENER, PROF. DR., *Carlsruhe*, **2**.
WINKEL, R., *Göttingen*, **18**.
WINKLER, PROF., *Freiberg*, **13**.
WINNECKE, PROF. DR., *Strasburg*, **11**.
WINTER, E., *Eimsbüttel, Hamburg*, **9**.
WÖHLER, PROF. DR., *Göttingen*, **13**.
WOHLERS (Successor to Campbell), *Hamburg*, **18**.
WOLCKER, PROF. DR., *Halle*, **18**.
WOLFF & SONS, *Heilbronn and Vienna*, **13**, **19**.
WÜLLNER, PROF. DR. (Polytechnic School), *Aix-la-Chapelle*, **10**, **12**.
ZEISS, C., *Jena*, **7**, **18**.
ZIEGLER, DR. A., *Freiburg, Breisgau*, **17**, **18**.
ZIMMER BROTHERS, *Stuttgart*, **3**, **15**.
ZORN, W., *Berlin*, **5**.

HOLLAND.

ASSEN SECONDARY GOVERNMENT SCHOOL, **3**, **8**.
BAKHUYZEN, H. G. VAN DE SANDE, *Director, Observatory, Leyden*, **11**.
BECKERS SONS, *West Zeedyk, Rotterdam*, **3**.
BLEEKRODE, DR. L., *The Hague*, **10**, **19**.
BOOGAARD, PROF. DR. J. A., *Director of the Museum of Anatomy, Academy of Leyden*, **18**.
BOSSCHA, PROF. J., *Royal Polytechnic School, Delft*, **10**, **13**, **17**, **18**.
BRONDGEEST, DR., *Physiological Laboratory and Ophthalmological School, Utrecht*, **18**.
BUYS-BALLOT, PROF., *Utrecht*, **3**, **6**, **8**, **11**, **14**, **15**, **18**.
DELFT ROYAL POLYTECHNIC SCHOOL, **10**, **13**, **17**, **18**.
DE LOOS, DR. D., *Director of the Secondary Town School, Leyden*, **8**, **13**.
DIRECTOR, The, of the Physical Laboratory, *University of Groningen*, **5**, **6**, **10**, **12**.
DONDERS, PROF., *Physiological Laboratory and Ophthalmological School, Utrecht*, **6**, **7**, **10**, **18**.
ENGELMANN, PROF., *Physiological Laboratory and Ophthalmological School, Utrecht*, **5**, **10**, **18**.
FERHAAR, A. T., *Utrecht*, **18**.
GRONEMAN, DR. F. G., *Director of the Secondary Government School, Groningen*, **4**.
GUNNING, DR. J. W., *Professor of Chemistry, "Athenæum Illustre," Amsterdam, and Scientific Adviser to the Treasury Department, Holland, Amsterdam*, **5**, **8**.
HARTING, PROF. DR. P., *University of Utrecht*, **18**.

Hoogewerff, S., Ph. D., *Rotterdam*, **5, 8**.

Huizinga, Prof., *Director of the Physiological Laboratory, University of Groningen*, **18**.

Mees, Prof. R. A., *Director of the Physical Laboratory, University of Groningen*, **5, 6, 10, 12**.

Mulder, Dr. M. E., *Groningen*, **18**.

Ottmans, H., 141, *Amstel Hooge Sluis, Amsterdam*, **18**.

Oudemans, Prof. A. C., *Royal Polytechnic School, Delft*, **13**.

Royal Polytechnic School (Prof. J. Bosscha) *Delft*, **10, 13, 17, 18**.

Rijke, Prof. Dr. P. L., *Director of the Cabinet of Physics, University of Leyden*, **3, 4, 6, 7, 8, 10, 11, 12, 18**.

School, Secondary Government, *Assen*, **3, 8**.

Scientific Society of Zeeland (G. N. de Stoppelaar, Sec.), *Middelburgh*, **18**.

Snellen, Dr., *Physiological Laboratory and Ophthalmological School, Utrecht*, **7, 15, 18**.

Snÿders, J. A., *Lecturer, Royal Polytechnic School, Delft*, **5, 18**.

Súringar, W. F. R., *Professor of Botany, University of Leyden, and Director of the Royal Botanic Gardens and Royal Herbarium*, **18**.

Teyler Foundation, The, *Haarlem*, **7, 9, 10, 11, 21**.

Van Ankum, Prof. U. J., *Zoological Laboratory, University of Groningen*, **18**.

Van de Sande Bakhuyzen, H. G., *Director of the Observatory, Leyden*, **11**.

Van Rijn, H. B. J., *Venlo*, **13**.

Verhaar, A. T., *Prosector, Veterinary School, Utrecht*, **18**.

Zeeland, Scientific Society of (G. N. de Stoppelaar, Secretary), *Middelburgh*, **18**.

ITALY.

Albini, Prof. G., *Director of the Physiological Institute, Royal University of Naples*, **18**.

Blaserna, Prof., *Director of the Institute of Physical Science, Royal University of Rome*, **20**.

Cacciatore, Prof. G., *Director of the Royal University, Palermo*, **20**.

Cantoni, Prof. G., *Director of the Institute of Physical Science, University of Pavia*, **20**.

Cecchi, Prof. F., *L. Pelli & Co.*, 12, *Viale Militare, Florence*, **20**.

Collegio Romano (Observatory), *Rome*, **20**.

Como, Liceo Volta, **20**.

Felici, R., *Director of the University of Pisa*, **20**.

Florence, Royal Institute "di Studii Superiori" (Sig. Peruzzi, President), **10, 11, 18, 20**.

Gambara, Prof. G., *Liceo Volta, Como*, **20**.

Giordano, Prof. G., *Director of the Cabinet of Physical Science, University of Naples*, **20**.

Legnazzi, Prof., *Royal University, Padua*, **20**.

Liceo Volta, Como, Cabinet of Physic and Chemistry (Prof. G. Gambara), **20**.

Modena, Royal University (Observatory), **20**.

Mossi, Dr. A., *Director of the University, Turin*, **20**.

Naples, Royal University of, **20**.

Naples, Vesuvian and Meteorological Observatory, **20**.

Observatory of the Royal University (Prof. D. Ragona, Director), *Modena*, **20**.

Observatory, Royal, *Palermo*, **20**.

Observatory, Collegio Romano, (Padre Secchi, Director), *Rome*, **20**.

Observatory, Royal, of the Campidoglio, *Rome*, **20**.

Padua, Royal University of, **20**.

Palermo, Royal Observatory, **20**.

Palmieri, Prof., *Director of the Vesuvian and Meteorological Observatory, Naples*, **20**.

Pavia, University of, **20**.

Pelli, L., 12, *Viale Militare, Florence*, **20**.

PERUZZI, SIG., *President of the Royal Institute "di Studii Superiori," Florence*, **10, 11, 18, 20**.

PISA, UNIVERSITY OF, *Pisa*, **20**.

PIZZORNO, F., *Bologna*, **8, 10**.

RAGONA, PROF. D., *Director of the Observatory, Royal University of Modena*, **20**.

RESPIGHI, PROF. L., *Director of the Royal Observatory of the Campidoglio, Rome*, **20**.

RIGHI, PROF. A., *Royal Technical Institute, Bologna*, **7, 10**.

ROME, COLLEGIO ROMANO (OBSERVATORY), **20**.

ROME, ROYAL UNIVERSITY, INSTITUTE OF PHYSICAL SCIENCE (Prof. Blaserna, Director), **20**.

ROME, ROYAL OBSERVATORY OF THE CAMPIDOGLIO, **20**.

ROSSETTI, PROF., *Director of the Cabinet of Physical Science, Royal University, Padua*, **20**.

ROYAL INSTITUTE "di Studii Superiori," *Florence* (Sig. Peruzzi, President), **10, 11, 18, 20**.

ROYAL LOMBARDIAN INSTITUTION OF SCIENCE AND LETTERS, **10**.

ROYAL UNIVERSITY, MODENA (OBSERVATORY), **20**.

ROYAL UNIVERSITY OF NAPLES, CABINET OF PHYSICAL SCIENCE (Prof. G. Giordano, Director), **20**.

ROYAL UNIVERSITY OF NAPLES, PHYSIOLOGICAL INSTITUTE (Prof. G. Albini, Director), **18**.

ROYAL UNIVERSITY OF PADUA, CABINET OF GEODESY AND HYDROMETRY (Prof. Legnazzi, Director), **20**.

ROYAL UNIVERSITY OF PADUA, CABINET OF PHYSICAL SCIENCE (Prof. Rossetti, Director), **20**.

ROYAL OBSERVATORY OF PALERMO (Prof. G. Cacciatore, Director), **20**.

ROYAL OBSERVATORY OF THE CAMPIDOGLIO (Prof. L. Respighi, Director), *Rome*, **20**.

ROYAL UNIVERSITY OF ROME, INSTITUTE OF PHYSICAL SCIENCE (Prof. Blaserna, Director), **20**.

SECCHI, PADRE, *Director of the Observatory of the Collegio Romano, Rome*, **20**.

TARANELLI, T., *Prof. of Physical and Natural Science, Technical School, Udine*, **20**.

TURIN, UNIVERSITY OF (Director, Dr. A. Mossi), **20**.

UDINE, TECHNICAL SCHOOL, **20**.

VESUVIAN AND METEOROLOGICAL OBSERVATORY (Prof. L. Palmieri, Director), *Naples*, **20**.

NORWAY.

DIETRICHSON, J. L. W., *Christiania*, **15**.

ESMARK, L., *Prof. of Zoology, University of Christiania*, **18**.

HOLLER, DR. F., *Selbo, Drontheim*, **3**.

MOHN, PROF. H., *Director of the Meteorological Institute of Norway, Christiania*, **14**.

SURVEY OFFICE, *Christiania*, **15**.

WELLESEN, *Christiania*, **8**.

RUSSIA.

ACADEMY OF SCIENCES, THE IMPERIAL, *St. Petersburg*, **3, 10, 11**.

ARGAMAKOFF (*Pedagogical Museum*), *St. Petersburg*, **19**.

ARSENAL, THE, *St. Petersburg*, **3**.

BAIRD, G., *St. Petersburg*, **12**.

BAULER (*Pedagogical Museum*), *St. Petersburg*, **19**.

BING, E., *Riga*, **1**.

BRAUER, G., *Wasili-Ostrof*, 22, *No.* 5, *St. Petersburg*, **3, 15**.

CHEMICAL LABORATORY (*Agricultural Institute*), *St. Petersburg*, **13**.

CHEMICAL LABORATORY (*Imperial Berg-Institute*), *St. Petersburg*, **13**.

CHEMICAL LABORATORY (*Michailow Artillery Academy*), **13**.

CHEMICAL LABORATORY (*Imperial Academy of Sciences*), *St. Petersburg*, **13**.

CHEMICAL LABORATORY (*Technological Institute*), *St. Petersburg*, **12, 13**.

Chemical Laboratory, *University of St. Petersburg*, **13**.
Chemical Society of Russia, *University of St. Petersburg*, **13**.
Czechovicz, C., *Gymnasium of Belostok*, **7**, **19**.
Dadiane, P. Nicholas, 80, *Grand Sadorai* (*log No.* 13), *St. Petersburg*, **1**.
Degen, Colonel, *Bobruisk*, **15**.
Ermolin (*Pedagogical Museum*), *St. Petersburg*, **19**.
Esersky, Theod., *St. Petersburg*, **1**.
Fenoult (*Pedagogical Museum*), *St. Petersburg*, **19**, **21**.
Givotovsky (*Pedagogical Museum*), *St. Petersburg*, **19**.
Gloukhoff, W. (Warden of Standards, Ministry of Finance), *St. Petersburg*, **5**, **8**, **14**, **19**.
Herbst, M. W., *Observatory*, *Pulkowa*, **15**.
Ilyin (*Pedagogical Museum*), *St. Petersburg*, **19**.
Imperial Establishment for the Preparation of Official Papers, *St. Petersburg*, **7**.
Imperial University, *St. Petersburg*, **9**, **10**, **21**.
Kovalsky (*Pedagogical Museum*), *St. Petersburg*, **19**.
Kresten (*Pedagogical Museum*), *St. Petersburg*, **19**.
Krivkovitch (*Pedagogical Museum*), *St. Petersburg*, **19**.
Lemström, Prof. S., *Helsingfors*, *Finland*, **10**.
Lermontoff (*Pedagogical Museum*), *St. Petersburg*, **19**.
Michailoff (*Pedagogical Museum*), *St. Petersburg*, **19**.
Mining Institute, *St. Petersburg*, **16**.
Mining School, *St. Petersburg*, **16**.
Moscow Juvenile and Pedagogical Library (*Pedagogical Museum*), *St. Petersburg*, **19**.
Nippe, R., *St. Petersburg*, **5**, **12**.
Nossoff (*Pedagogical Museum*), *St. Petersburg*, **19**.
Observatory, the Imperial, *Pulkowa*, **11**, **14**, **15**.
Observatory, *Wilna*, **11**.
Oettingen, Professor Dr. A. von, *Imperial University*, *Dorpat*, **14**.
Oussoff, Dr. M., *Zoological Museum of the University*, *St. Petersburg*, **18**.
Ovsiannikow, Ph., M. Acad. Sc., *Professor of Physiology*, *University St. Petersburg*, **18**.
Paschkiewitch, Captain W., *Central Administration of Artillery*, *St. Petersburg*, **3**.
Pedagogical Museum, *St. Petersburg*, **19**, **21**.
Penkin (*Pedagogical Museum*), *St. Petersburg*.
Petroff, *Kalouga*, **1**.
Physical Science Cabinet (*Imperial Academy of Sciences*), *St. Petersburg*, **3**, **10**.
St. Petersburg Workshop of School Apparatus (*Pedagogical Museum*), *St. Petersburg*, **19**.
Schildknecht (*Pedagogical Museum*), *St. Petersburg*, **19**.
Schindhelm (*Pedagogical Museum*), *St. Petersburg*, **19**.
Shulgin (*Pedagogical Museum*), *St. Petersburg*, **19**.
Skibinevsky (*Pedagogical Museum*), *St. Petersburg*, **19**.
Statistical Committee (*Pedagogical Museum*), *St. Petersburg*, **19**.
Strembitsky (*Pedagogical Museum*), *St. Petersburg*, **19**.
Stroukoff (*Pedagogical Museum*), *St. Petersburg*, **19**.
Tchebichef, Prof. P., *The University*, *St. Petersburg*, **2**, **4**.
Technical Society, The Imperial, *St. Petersburg*, **3**.
Technological Institute, *St. Petersburg*, **3**, **12**.
Technological Institute, *The Physical Laboratory of*, *St. Petersburg*, **3**, **5**, **10**, **12**.
Telegraphs, General Direction of, **10**.
Topographical Department of the Imperial Russian General Staff, *St. Petersburg*, **7**, **15**.
Topographical Department of the Imperial Russian General Staff, *Tiflis*, **15**.
Tsitovitch, General (*Pedagogical Museum*), *St. Petersburg*, **19**.
Wild, Dr. H., *Central Physical Observatory*, *St. Petersburg*, **14**.
Zinger, Colonel, *Pulkowa*, **10**.
Zooeff (*Pedagogical Museum*), *St. Petersburg*, **19**.

SPAIN.

Academy of Sciences, *Madrid*, **11**.

Archæological Museum, *Madrid*, **11**, **15**.

Astronomical Observatory, *Madrid*, **11**.

Botella y de Hornos, B. Federico de, 34, *Calle de San Andres, Madrid*, **15**.

Calderon, S., *Plaza de Santa Barbara, Madrid*, **16**.

Comision del Mapa Geologico de España, 23, *Calle de Isabel la Catolica, Madrid*, **15**.

Geographical and Statistical Institute of Spain, *Madrid*, **15**.

Ministry of Marine, *Madrid*, **15**.

Quiroga, F., 8, *Union, Madrid*, **16**.

Saavedra, E., 14, *Calle de San Joaquin, Madrid*.

SWITZERLAND.

Baumgartner, H., 14, *Heumattstrasse, Basle*, **3**.

Bernoullianum, The, *Basle*, **8**, **9**.

Brocher, L., 45, *Boulevard des Tranchées, Geneva*, **15**.

Cauderay, J., 15, *Rue St. Pierre, Lausanne*, **10**.

Colladon, Prof. D., 1, *Boulevard du Pin, Geneva*, **3**, **4**, **5**, **6**, **10**, **12**.

De la Rive, L., *Geneva*, **8**, **10**.

De la Rive Collection, *Geneva*, **5**, **7**, **10**.

De Saussure, H., *Geneva*, **10**, **14**.

Ekegrén, H. R., *Geneva*, **3**.

Favre, E., 6, *Rue des Granger, Geneva*, **15**.

Forel, Prof. Dr. F. A., *Morges*, **14**.

Geneva Association for the Construction of Scientific Instruments, *Geneva*, **2**, **3**, **4**, **5**, **7**, **8**, **10**, **11**, **14**, **15**, **18**.

Goldschmid, J., *Zurich*, **14**.

Hagenbach-Bischoff, Prof. Dr. E., *Institution for Physical Science at the Bernoullianum, Basle*, **8**, **9**.

Hermann, Prof. Dr. L., *Physiological Laboratory, University of Zurich*, **7**, **18**.

Linder, G., 29, *Gerbergasse, Basle*, **10**.

Mousson, Prof. A., *Zurich*, **5**, **7**.

Pictet (Raoul) & Co., *Geneva*, **8**.

Ramboz and Schuchardt, *Geneva*, **14**.

Recordon, Prof. E., 53, *Terrassière, Geneva*, **11**, **12**, **15**.

Sarasin, G., *Tour de Balessart, Geneva*, **2**, **11**, **15**.

Schmid, A., *Engineer, Zurich*, **3**.

Soret, L., *Geneva*, **7**, **8**, **13**, **14**.

Soret, Perrot, and Sarasin (De la Rive Collection), *Geneva*, **5**, **7**, **10**.

Stapff, Dr. F. M., *Geological and Mining Engineer, St. Gothard Railway*, **1**.

Wartmann, E., *Professor of Natural Philosophy, University of Geneva*, **8**, **10**.

Wolf, Prof. R., *Dirèctor of the Observatory, Zurich*, **14**.

CATALOGUE.

SECTION 1.—ARITHMETIC.

West Gallery, Ground Floor, Room G.

I.—SLIDE RULES.

1. Slide Rule, of boxwood, arranged by Mr. Dixon, Lowmoor Ironworks. *Aston & Mander.*

In addition to the lines of the ordinary slide rule this instrument contains :
Lines of common and hyperbolic logs and numbers.
Lines of sines, cosines, and numbers.
Lines of cubes and roots, direct.
A copy of Dixon's " Slide Rule Practice " is issued with each rule.

2. Slide Rule, of ivory, showing the actual and racing tonnage of yachts. *Aston & Mander.*

The length and breadth of beam being " set," as directed in the instructions, the tonnage of yachts of any size is shown as marked.

3. Slide Rule, of boxwood, adapted to brickwork measurement in all its branches. *Aston & Mander.*

In this adaptation of the rule to brickwork measurements, all the results are obtained by one setting, viz., length and height; while, immediately opposite, any thickness will be found; the superficial area in square feet; the contents in rods of reduced work, $1\frac{1}{2}$ bricks, in cubic feet, in cubic yards, and the number of bricks required.

4. Slide Rule, of boxwood, adapted to timber measurement in all its branches, giving the superficial or cubic contents of round and unequal sided timber, St. Petersburg standard. *Aston & Mander.*

5. Slide Rule, of boxwood, with reversible slides, movable inverted lines, &c. *Aston & Mander.*

Uses explained in Hoare's " A. B. C. of Slide Rule Practice."

6. Slide Rule, of ivory, with reversible slides, movable inverted lines, &c. *Aston & Mander.*

Uses explained in Hoare's " A. B. C. of Slide Rule Practice."

7. Slide Rule, of ivory, adapted for use in iron and steel plate and sheet rolling mills. *Aston & Mander.*

This rule will show directly the precise net and waste weight of iron and steel plates, and sheets, of any size, shape, and thickness. It may be applied to all ordinary metals, and to find areas, cubic contents, liquid capacity, &c.

8. Slide Rule, of boxwood, adapted for sheet iron and steel manufacturers. The dimensions, thicknesses, and weights are given both in English and metrical standards.

Aston & Mander.

The length of the sheet or plate (on the slide) being first set to the width, then immediately below any thickness (on the top lines) will be found (on the slide) the actual weight of the sheet either in pounds (avoirdupois) or kilogrammes.

9. Slide Rule, of ivory, adapted for use in iron and steel-bar rolling mills, showing instantly the precise net and waste weights for bars of any length, size, and form. *Aston & Mander.*

9a. Three Slide Rules. *Elliott Brothers.*

10. Estimator. A sliding rule, by which the volume of prismoidal bodies (embankments, ditches, cuttings, &c., occurring in the construction of railroads, canals, fortifications, &c.,) is calculated mechanically.

Dr. F. M. Stapff, Geological and Mining Engineer at the St. Gotthard Railway.

This instrument, invented by the exhibitor, is patented in Sweden and the United States of America.

11. Set of Gauging Instruments. *Dring and Fage.*

Head rod. For ascertaining the head diameter of a cask, and working out the contents.

Bung rod and slide. For finding the bung diameter and diagonal of a cask. The rod is divided into inches and tenths, with a line of imperial area and diagonal line; this last gives the approximate content without calculation, and is computed on the assumption that most casks are similar to one another in form, and therefore vary as the cubes of their like dimension.

Long callipers used for finding the internal length of a cask from head to head.

Cross calliper. Used for finding the external diameter of a cask.

Stave gauge. For finding the thickness of the stave in a cask.

11a. A Timber Rule, for finding the content of timber of any form, regular or irregular. The rule has eight gauge points or divisors for reducing dimensions in inches to contents in square feet. *Dring and Fage.*

11b. "Verie" or Excise Officer's Rule.

Dring and Fage.

Verie is probably a corruption of "Vero," a revenue officer who made an alteration in the method of laying down some of the lines on the rule; previously to which they were called Everard's rules.

The lines on the rule are the A, B, C, D, MD, (or malt depth) 6x or variety lines, viz., 1st, 2nd, 3rd, 4th, Dr. Hutton's and Dr. Young's, and two ullage lines (segment standing and segment lying).

The A, B, C, and D lines are commonly called Gunter's lines (from Gunter the celebrated mathematician, who was the first to apply a logarithmic line for the instrument to the solution of arithmetical problems) of which the A, B, and C, are merely repetitions of each, and laid down to single radius, and the D to double radius.

The MD line is similar to the A, B, and C, but is a broken line of two radii, with the figures and divisions in an inverted order (reading from right to left), commencing at 2218·192 in the right-hand radius, and ending at the same point in the left-hand radius, 2218·192 being the number of inches in a bushel. By the method in which this line is arranged and used in conjunction with the A, B, and C lines the contents in bushels of rectangular and similar figures may be found at one operation.

The X or variety lines or lines of special gauge points (invented by Mr. Woolgar) for finding the mean diameter of a cask whatever its form; these lines commence at 18·789, the circular gauge point, and are extended according to each variety to which they may be applied.

The ullage lines are rules for finding the contents of a cask by comparison with a standard cask holding 100 gallons, a form nearest those frequently occurring in practice.

It cannot be ascertained by whom these lines were invented.

The fixed gauge points on the rule are those for the imperial gallon and bushel, both square and round.

These rules are principally used by excise officers and maltsters. So admirable is the arrangement, that nearly every problem to which the principle of the slide rule is applicable can be solved on one of these rules.

11c. Slide Rule, invented by Mr. Coulson, of Redan, used for setting out railway curves, finding the weights of materials from their specific gravities, breaking strains, &c.

Dring and Fage.

The applications of this rule are so varied that the author's description of them exceeds 400 octavo pages of closely printed matter.

12. Slide Rule, by M. Mabire.

Conservatoire des Arts et Métiers, Paris.

12a. Cylindrical Reckoning Rule. (This rule belongs to the Conservatoire des Arts et Métiers.)

M. Mannheim, Professor at the Polytechnic School, Paris.

13. Calculating Rules, 1 of 50 cm., 1 of 36 cm., 1 of 26 cm., as arranged by M. Mannheim.

M. Tavernier Gravet, Paris.

13a. Small Cylindrical Calculating Machine. Arranged by Herr Mannheim. *Conservatoire des Arts et Métiers, Paris.*

14. Pocket Calculator, arranged by Major-General A. De Lisle, R.E., for the use of engineers. *Elliott Brothers.*

This slide rule is useful for finding the weight of various materials, with the help of the small tables on the back, for checking bills of quantities, and for all approximate calculations required in engineering practice. The slides are:—

On Face.

On Stock—A. The ordinary logarithmic line.
I. The same inverted.
On Slides—Upper I. Inverted line.
„ D. Line of squares.
Lower B. Ordinary logarithmic lines.
Tan, Sin } Trigonometric lines.

Special Marks—
M. Modulus of logs. to find prop. parts of logs.
A. Reciprocal of M. to find hyperbolic logs.
S″ To find length of arcs, &c.
R′ Radius for minutes.
R Radius for seconds.

On Back.

On Stock—D. Line of squares.
On Slide—E. Line of cubes read with D on line of $\frac{3}{2}$ powers read with A.
F. Line of $\frac{5}{2}$ powers read with D, or of $\frac{5}{4}$ powers read with A.
Tables and useful Numbers.

Line E with A gives variation in depth of water running over weir due to alteration of length of weir. Neville's Hydraulics, page 22. 3rd edition.

A	$143=d$	
E	$220=l$	$60=l'$
A		$6=d$

Line F with D assists in finding the dimensions of a pipe or channel, with a given hydraulic inclination to discharge a given quantity from the calculated discharge of a pipe or channel of known dimensions and the same inclination. Thus, if a pipe 4″ diameter discharge 15 cubic feet per minute, what diameter will discharge 33 cubic feet. Neville's Hydraulics, page 245.

D		
F	$15=D$	$33=D'$
D	$4=d$	$5.48=d'$

The two slides on the face working together solve the following equations:—

$$x=\frac{ab}{cde};\ x=\frac{abc}{de};\ x=\frac{abcd}{e}$$

15. Slide Rule, of boxwood, with double slide.
Renaud-Tachet, Paris.

16. Routledge's Original Engineers' Slide Rule and manuscript book of instructions for using it.
Lent from the Patent Office Museum by the Commissioners of Patents.

17. Kentish's Compound Slide Rule.

Dring and Fage.

This is a new and ingenious arrangement of Gunter's lines, by means of which problems in trigonometry and navigation can be solved, in addition to those ordinarily done on the slide rule.

17a. Dr. Roget's Slide Rule of Involution.

W. H. Prosser.

This rule exhibits at one view all the powers and roots of any given number. It is a measure of the powers of numbers, in the same way as Gunter's scale is a measure of their ratios. Described in Phil. Trans. 1815, Part 1.

17b. Slide Rules (3), with double sliders, being suggested improvements on the ordinary slide rule, giving greater clearness in reading off, and avoiding complication in the lines.

W. H. Prosser.

17c. Glass Slide Rule, invented by Léon Lalanne.

W. H. Prosser.

This rule is made of two slips of card, upon which the scales are printed. The slider, also made of card, has scales, constants, and gauge points printed on both sides, and moves between the two slips. The whole is enclosed between two pieces of glass.

17d. Slide Rule, with only one slider, adapted for the pocket-book. Arranged by J. W. Woollgar. *W. H. Prosser.*

18. Salleron's Slide Rule for reduction of volumes of gases to standard temperature and pressure.

The Council of the Yorkshire College of Science.

19. Salleron's Slide Rule for reducing barometric heights to standard temperature.

The Council of the Yorkshire College of Science.

II.—CALCULATING MACHINES.

20. Calculating Machine, adapted to trigonometrical computations, invented by Sir Samuel Morland (1625–1695), and constructed by Henry Sutton and Samuel Knibbs of London, in 1664. Formerly belonging to Mr. C. Babbage, F.R.S.

Major-General Babbage.

On the lid of this machine is the following inscription :
" Machina Cyclologica Trigonometrice Quâ Tribus datis, reliqua omnia in Triangulis Planis Quæsita faciliter atque unico intuitu expediuntur—a Samuele Morlando inventa—Anno Salutis MDCLXIII.

21. Calculating Machine, designed by Viscount Mahon, afterwards third Earl Stanhope (1753–1816), and constructed by James Bullock in 1775. Formerly belonging to Mr. C. Babbage, F.R.S. *Major-General Babbage.*

22. Calculating Machine, designed by Viscount Mahon, afterwards third Earl Stanhope (1753–1816), and constructed by James Bullock in 1777. Formerly belonging to Mr. C. Babbage, F.R.S. *Major-General Babbage.*

23. Babbage's Calculating Machine; or Difference Engine. *Exhibited by permission of the Board of Works.*

This machine was invented by the late Mr. Charles Babbage, F.R.S., who was born on the 26th December 1791, and died on the 18th October 1871.

Its construction was commenced in 1823 by authority, and at the cost of the Government, and was carried on for several years under Mr. Babbage's gratuitous supervision. The work was suspended in 1833, and after many delays, Mr. Babbage was informed in November 1842 that the Government regretted the necessity of abandoning the machine, alleging the expense of its completion as the ground for their decision.

At the time of its suspension about 17,000*l.* had been expended by Government upon its construction, and a large part of the machinery had been made. The small portion now exhibited was put together in 1833, prior to the suspension of the work, in order to show the action of the machinery.

The whole engine, when completed, was intended to have had 20 places of figures and 6 orders of differences.

This machine was expressly designed for the purpose of calculating and printing tables, and not to perform single arithmetical sums.

If a single article is wanted, it is not, generally speaking, worth while to construct a machine to make it; but, when large numbers are required, their production comes within the true province of machinery, and in this sense the Difference Engine is emphatically a machine for manufacturing tables.

The mode in which the Difference Engine calculates tables is, by the continual repetition of the simultaneous addition of several columns of figures to other columns, in the manner more particularly described below, and printing the result.

In the small portion put together, and now exhibited, the figure opposite the index on the lowest wheel visible, in all cases, represents units; the figure on the next wheel above, tens; that on the one above it, hundreds; the next thousands, and so on.

The right hand column of wheels shows the result of the calculation or the tabular number; for instance, series of squares, cubes, or logarithms, &c. appear upon it, according to the nature of the calculation the machine is making.

The next or central column represents the First Difference, and the left hand column the Second Difference. At the bottom of the central column is a figure wheel, covered, which can be used as a third difference, so as to enable this portion of the machine to calculate tables of which the Third Difference does not exceed 9. This will be better understood if this last wheel is supposed to represent the lowest wheel of a fourth column of figures standing beyond the left hand side of the machine, as it would be if it formed part of the complete machine.

This arrangement is effected by a movable platform, with axles, and gearing wheels upon them, which are used for adding from the third difference wheel

at the bottom of the central column to the second difference which is shown on the left hand column. The effects capable of being produced by this mechanism, when the gearing is altered, and the loose wheels belonging to it are put into gear with certain figure wheels, is explained in Babbage's Ninth Bridgewater Treatise, together with the new views which it opened up to him upon the subject of natural laws.

The three upper wheels of the left hand column are separated from the rest of the machine, and are employed in counting the natural numbers. In other words, they register the number of calculations made by the machine, and give the natural numbers corresponding with the respective terms of the table.

Four half turns of the handle, two backwards and two forwards, are required for each calculation, and the words "calculation complete" come round upon a wheel at the top of the central column to show when this is done. This wheel also shows, by the word "adjust," in what position of the handle the figure wheels may be freely moved by hand, in order to introduce different numbers or a different table.

24. Scales, of boxwood, to show cubes, squares, and roots, areas, diameters, circumferences, and decimal equivalents.

Aston & Mander.

The bevel edged set square is used to read the divisions, and dispenses with the need of voluminous tables.

25. Panometer, or Calculating Machine.

Edward Grohmann, Vienna.

By this extremely simple apparatus, various arithmetical computations can be performed with great readiness.

25a. Calculating Machine for Multiplication.

P. Nicholas Dadiane, St. Petersburg.

26. Calculating Machine, for performing complex arithmetical operations; invented by M. Thomas of Colmar.

Professor Hennessy, F.R.S.

26a. Calculating Machine for Adding, Subtracting, Multiplying, and Dividing.

Theodore Esersky, St. Petersburg.

26b. Small Calculating Machine, encased in a pocket-book. *Theodore Esersky, St. Petersburg.*

26c. Ten Copies of Multiplication and Division Tables.

Theodore Esersky, St. Petersburg.

27. Wertheimber's Calculating Machine, applicable to wheel work. Patent, No. 9616—1843.

The Committee, Royal Museum, Peel Park, Salford

28. "Napier's Bones" or Rods (obsolete). Made about 1700. *Dring and Fage.*

Invented by Baron Napier, the originator of logarithms, used for performing division and multiplication.

28a. Set of Napier's Bones. 16th century.

Lewis Evans, Hemel Hempsted.

29. Calculating Disc, size about 18 centimeters, with double divided circle; constructed on the system of Prof. Sonne, cf. No. **4002.** *Landsberg and Wolpers, Hanover.*

30. Calculating Disc, with index of logarithms.
Landsberg and Wolpers, Hanover.

31. Calculating Disc, pocket apparatus.
Landsberg and Wolpers, Hanover.

32. Calculating Circle, 0·08 meters in diameter, with single scale of brass. *Rudolf Weber, Aschaffenburg.*

33. Calculating Circle, 0·15 meters in diameter, with single square and cubic scale. *Rudolf Weber, Aschaffenburg.*

The circles are on account of their continuous scale more convenient and more accurate than straight slide rules. They are, therefore, peculiarly adapted as pocket instruments for practical purposes, and can be relied on to be as accurate as logarithms to four places.

34. Cubing Circle, 0·08 meters in diameter, for ascertaining the cubical contents of trees in forests.
Rudolf Weber, Aschaffenburg.

The cubing circle is to be noted as giving the index numbers for obtaining the cubical contents of *standing* (not felled) timber; these have been obtained from practical experiments carried out by the Government Department of Forests in Bavaria on more than 40,000 trunks of different kinds of trees. The circle may be relied on for great accuracy in forest valuation.

35. Calculating Instrument, invented by Sir S. Morland.
Bennet Woodcroft, F.R.S.

35a. Calculating Planisphere. *Royal College of Science.*

35b. McFarlane's Calculating Planisphere.
The Committee, Royal Museum, Peel Park, Salford.

36. Calculating Machine, designed by the Vicar Hahn of Echterdingen, in 1770–1776; constructed by his son, Court Mechanician in Stuttgart, in 1809; fourth specimen.
Her Highness the Duchess of Urach.

The machine which is exhibited is on exactly the same principle as that of the one now in general use which was invented by Thomas, the only difference being that in Thomas's machine the numbers are placed in straight lines, and in that of Hahn in a circle. It must have served as a model for the machine of Thomas. The machine is to the present day in perfect order, and works calculations up to numbers of 12 digits.

37. Logarithmic Calculation Apparatus, with *one* folding scale, five meters in length.
Prof. Gustav Hermann, Aix-la-Chapelle.

Calculation by means of this instrument is effected with the use of only one scale. The two revolving arms are used like a compass. When the logarithm

of a quotient $\frac{a}{b}$ has been fixed between the arms, the plate must be turned until the one arm is brought to a factor c, the product $\frac{a}{b}c$ will then be read on the other arm. This arrangement admits of the scale being made as long as may be necessary by breaking it into lengths, without rendering the instrument inconvenient. In the exhibited instrument ten circles are used, by which means the scale attains a length of five meters, and is accurate up to $\frac{1}{10000}$. In using the instrument care must be taken to mark the number of each scale circle, which can be fixed by small sliding buttons. The number of the circle on which the result is to be read is found by the same rules as the characteristic of a logarithm, on the supposition that the ten scale-circles form a graphic table of logarithms of all the natural numbers, the base of the system being $\sqrt[10]{10}$.

38. Arithmetical Disc, a very simple calculating machine, with accompanying description. *Prof. Prestel, Emden.*

39. Calculating Machine, of the last century.
The Royal Gewerbe Academy, Berlin (Director Prof. Reuleaux).

This calculating machine formed part of the legacy of Hofrath Beireis, the well-known physicist and chemist in the 18th century, and is very similar to the calculating machine, No. **36**.

40. Tide Calculating Machine.
Sir William Thomson, F.R.S.

41. Pascal's Calculating Machine (1642).
Conservatoire des Arts et Métiers, Paris.

42. Petroff's Arithmetical Apparatus.
M. Petroff, Master at the School, Kalouga.

43. Arithmometer, with measuring apparatus, and the full size skeleton of the square metre and cubic metre, folding up by means of a hinge. *Frère Memoire Piron.*

44. Counters and Speed Indicators.
T. R. Harding and Son.

(*a*.) Counters with reciprocating motion, as applied to marine and stationary engines.

Counters with rotary motion, suitable for shafting, printing, and other machinery.

Small counters with rotary motion applicable to spinning machinery and various other purposes.

Speedometers or pocket counters for ascertaining the speed per minute of spindles or quick running machinery up to 10,000 revolutions per minute.

(*b*.) Counters actuated by pneumatic and electric apparatus at a distance from the motion to be indicated.

(*c*.) Speed indicators, showing by the height of a column of mercury the actual speed, at any moment, of engines and other machinery.

45. Model of Gas Meter Counting Machine.
Council of King's College, London.

46. Cavendish's Original Counting Machine.
Council of King's College, London.

47. "The Motometer," a machine to indicate the number of revolutions made per minute, or other portion of time, by a steam engine or revolving shaft or other body having intermittent motion, so that by simple inspection of a dial the rate of speed may be seen. *H. Faija.*

This instrument is constructed so as to indicate by a positive motion direct from the engine or other moving body to which it is attached, and is of purely mechanical construction independent of all centrifugal and other forces of an indirect nature. The indication is consequently absolute and not comparative.

The instrument is made in four different forms according to requirements; for instance,—

No. 1 is intended for slow motions, as in pumping engines, &c., where each separate revolution is indicated.

No. 2. For all ordinary marine and stationary engines with speed varying from 20 to 100 revolutions per minute, in which case the speed is indicated at every tenth revolution.

No. 3. To indicate extremely high speeds, such as locomotives, &c.

No. 4. To indicate at the termination of each minute the exact number of revolutions made during that minute.

The machine exhibited is No. 2, being the form adapted to most general purposes.

III.—MISCELLANEOUS.

48. Apparatus for the Statistical Treatment of large numbers of Seeds, &c., to sort them rapidly into classes differing by regular gradations of magnitude, with the view of testing how far the relative numbers in the several classes accord with the results of the Law of Error or Dispersion.
Francis Galton, F.R.S.

It consists of a box, with bars parallel to one another, and having a bevelled edge, fixed horizontally across its top. There is also a frame of other bars, held together like those in a gridiron, that lie on the top of the box between these. Consequently, when the frame is pulled forwards as far as it can go, each of its bars closes along its whole length against one of the fixed bars, and when it is pushed gently back the framework bars separate simultaneously and equally from the fixed bars, and any objects that may have been laid in the bevel between their edges, and are small enough, will drop through. The framework is moved by a screw turned by a ratchet wheel, which is itself moved by the to-and-fro action of a handle between stops, one of which is adjustable at pleasure. Hence, every time the handle is worked, the space between the bars is widened by a definite space, and all the seeds, &c., whose diameter is greater than the original and less than the final space, will drop

through. A tray, divided into compartments, slides beneath the box; it is pushed forward through the space of one compartment before giving a fresh movement to the handle, and thus the seeds become sorted into the different compartments. (This instrument was used to illustrate a lecture before the Royal Institution on Friday evening, February 27, 1874.)

49. Apparatus affording Physical Illustration of the action of the Law of Error or of Dispersion.

Francis Galton, F.R.S.

Shot are caused to run through a narrow opening among pins fixed in the face of an inclined plane, like teeth in a harrow, so that each time a shot passes between any two pins it is compelled to roll against another pin in the row immediately below, to one side or other of which it must pass, and, as the arrangement is strictly symmetrical, there is an equal chance of either event. The effect of subjecting each shot to this succession of alternative courses is, to disperse the stream of shot during its downward course under conditions identical with those supposed by the hypothesis on which the law of error is commonly founded. Consequently, when the shot have reached the bottom of the tray, where long narrow compartments are arranged to receive them, the general outline of the mass of shot there collected is always found to assimilate to the well-known bell-shaped curve, by which the law of error or of dispersion is mathematically expressed. (This arrangement was devised, by the exhibitor, to illustrate a lecture before the Royal Institution on Friday evening, February 27, 1874.)

50. Practical Approximation to the value of the circumference in terms of the diameter, by means of a right angled triangle having one acute angle $=27° \, 35' \, 49{\cdot}636''$.

Edward Bing, Riga.

For the purpose of effecting this object, as well as for answering kindred questions, use is made of a triangle, specimens of which are here exhibited, and of which one angle is a right angle and another is defined by an equation.

SECTION 2.—GEOMETRY.

West Gallery, Ground Floor, Room G.

I.—INSTRUMENTS USED IN GEOMETRICAL DRAWING.

52. Pantograph.

Royal School of Industry, Cassel. (*Dr. W. Narten.*)

This pantograph was made for the geodetic collection of the school, in the year 1866, by Messrs. Breithaupt and Son, Cassel. It is used for enlarging and diminishing maps and plans. Peculiar to this construction is the movement of all the arms in points, by which means friction is as far as possible avoided. The employment of tubes instead of the usual rectangular bars is also to be recommended, as by this means all bending, which creates errors in the use of the instrument, is avoided; besides which, the weight of the whole is considerably decreased, thus also lessening friction in the movement of the points.

The peculiar construction of this pantograph was invented and carried out by Messrs. Breithaupt and Son, and the instrument possesses in consequence great accuracy and facility of use.

53. Pantograph. *Renaud Tachet, Paris.*

54. Pantograph, with free hanging arms of new construction.

Albert Ott and Gottlieb Coradi, Kempten.

By means of this instrument figures on a reduced or an enlarged scale can be transferred either on paper, stone, or metal.

These pantographs differ in their construction from other similar instruments by not resting on friction-rollers, but are freely suspended by means of elastic metal wires from cast-iron *crane*-like frames; thus only a small portion of each instrument rests on the table. The advantages of this construction are these: easy and secure management of the instrument; any ordinary table may be used of a size sufficient to afford room for the stands, the original, and copy; the accuracy of the graphic representation is greater at less cost.

The guidance of the instrument is so easy and so accurate that with a little practice every outline can be graphically reproduced. Drawings, likewise, can be transferred on substances measuring a certain height, such as lithographic stones, it being only necessary to place frame and original correspondingly higher. In producing enlarged copies both the guiding peg and the drawing pencil must be exchanged, and the releasing cord fastened accordingly. The guidance, in making enlarged copies, is also performed with the handle of the tracing pencil with the same accuracy as when making reduced copies.

54a. Horizontal Pantograph, traversing a surface of 36 inches in length by 20 inches in width. Reduction from $\frac{1}{2}$ to $\frac{1}{12}$.

L. Oertling.

54b. Pantograph, large model, with double scale and reverse action, belonging to the Indian service. Four of these large instruments are now in use. *M. Adrian Gavard, Paris.*

54c. Frame, containing the figures of pantographs and pantopolygraphs drawn with the above instrument.

55. A Large Collection of Mathematical Instruments for **Geometrical** and **Fortification Drawing,** as well as for **Artillery purposes.** Property of His Highness the Prince Pless, Fürstenstein. *Committee of Breslau.*

This ancient collection, dating from the commencement of the last century, is remarkable for the excellent workmanship and good state of preservation of the instruments.

It contains 19 compasses and 11 accessory parts, 28 rules and scales, two of the same with two keys for fortification drawing, eight triangles and set squares, 10 protractors, two pantographs, and 52 other instruments. In all, 134 pieces.

56. Case of Mathematical Instruments.
Renaud Tachet, Paris.

57. Proportional Compasses. *Renaud Tachet, Paris.*

58. T-squares, Set Squares, and Curves.
Renaud Tachet, Paris.

59. Diagonal Scale.
Geneva Association for Constructing Scientific Instruments.

60. Scales made of **Mica,** for use in geometrical drawing (*see* Nos. **275, 879, 2591, 3468,** &c.).
Max. Raphael, Breslau.

61. Perspective Apparatus invented by James Watt.
Bennet Woodcroft, F.R.S.

62. Complete Set of Mathematical Instruments, with all the modern improvements; as used by professional draughtsmen, &c.; illustrated by diagrams of work performed.
Wm. Ford Stanley.

62a. Magazine Case of Drawing Instruments.
Henry Porter.

64. A Case of Mathematical Instruments, probably Dutch, made at the beginning of the 18th century.
Lewis Evans.

65. Two Cases of Drawing Instruments. *Mark Eames.*

66. Beam Compass, T-squares, Set Squares, and Curves. *Bock and Handrich, Dresden.*

67. Models of Mathematical Instruments. The ortho-compass and the addition compass. *Prof, L. Zmurko, Lemberg.*

The first of these instruments is constructed so that the points of the compass are always parallel to each other, and perpendicular to the surface of the paper. The second is a compass which can be used also as a protractor, as it contains an apparatus which indicates the amount of opening between the arms.

69a. Photographs of Mathematical Instruments. *Otto Fennel, Cassel.*

69d. Révoil Tele-iconograph, altered for perspective drawings enlarged to 20 times on a horizontal plane-table. *M. Georges Sarasin, Geneva.*

The instrument consists of a telescope, adapted to a Wollaston *camera lucida,* and fixed on a stand arranged so as to make it a mathematical or scientific instrument. In order to facilitate the exact grouping of the partial perspectives in accordance with a general cylindrical perspective, and capable of being developed, and in order to permit of drawing while the telescope is inclined at great angles, the following additions have been made to the Révoil model:—1st. A tightening ring with an adjusting screw on the thread of the screw which fixes the prism on to the eye-piece. 2d. A web of six threads crossed at right angles in the focus of the object glass. 3d. A spirit level on the telescope stand. 4th. A socket and rack joint, permitting of the height of the instrument being adjusted above the drawing. 5th. A graduated scale with vernier, giving a reading to five minutes on the horizontal limb. 6th. A method of attaching the instrument to its stand, so as to be at the same time firm and easy to work.

69e. Set of Instruments for Geometrical Drawing. *See* Appendix, page 915. *E. G. Richter and Co., Chemnitz.*

II.—INSTRUMENTS FOR TRACING SPECIAL CURVES.

70. Conograph. An instrument by which the various conic sections may be drawn.

a. Ellipso-Parabolograph.
b. Hyperbolograph.

Dr. Lawrence Zmurko, Lemberg.

This instrument consists of two movements independent of, and perpendicular to, each other; the first of these is set in action by turning a disc, the second by means of a spring. These movements are so contrived that the extent of the second motion shall be such a function of that of the first as to cause a conic section to be described.

71. Cycloidograph. An instrument for tracing cycloids. *Dr. Lawrence Zmurko, Lemberg.*

71a. Instrument for tracing with accuracy ellipses and spirals up to 25 centimetres. *M. Adrian Gavard, Paris.*

72. Instrument for drawing **Conic Sections.**
Edward Uhlenhuth, Anclam, Pommerania.

This instrument, which was invented by the exhibitor, shows in the first place the formation of the parabola. By altering the arrangement according to the instructions given in the sketches on the drawing board, the construction of the ellipse and hyperbola easily follows.

73. Elliptic Compass. *Renaud-Tachet, Paris.*

74. Colonel Peaucellier's Compound Compass.
Conservatoire des Arts et Métiers, Paris.

75. Compound Geometric Chuck, producing the kinematic retrogressive parabola, by continuous motion; either on a moving plane by a fixed point, or on a fixed plane by a moving point. *Henry Perigal, F.R.A.S.*

76. Machine for **Compounding two Simple Harmonic Curves.**
Invented and constructed by A. E. Donkin, M.A., Rugby School.

A strip of paper is wound round the cylinder; the little glass pen moving backwards and forwards on it draws one curve, a similar motion of the cylinder the other. Since both move at once the curves are combined, and the result rendered visible to the eye by the revolution of the cylinder.

A. Eccentric for giving simple harmonic motion to pen.
B. „ „ „ cylinder C.
D.⎫ wheels for determining relative numbers of vibrations of pen and
E.⎭ cylinder.
F. Wheel for transmitting slow motion to pinion G which turns the cylinder.
H. Idle wheel.
I. Change wheels to supply different ratios of vibration of pen and cylinder.

76e. Spherical Rules and Squares for Spherical Drawing. *Dumoulin Froment, Paris.*

76a. Working Model of a Trace-Computer, designed by the Exhibitor, for the use of the Meteorological Office.
Francis Galton, F.R.S.

Given two ordinates having the same abscissa, the instrument, of which this is a working model, pricks out a third ordinate that shall be some desired function of the other two. The original instrument was contrived for the use of the Meteorological Office, where it is employed to derive a trace for humidity from the traces of the dry and wet bulb thermometers. It consists of a hori-

zontal slab, whose upper surface has been shaped, as hereafter described, in accordance with numerical tables, calculated from the desired function, the height of its surface at each point being the tabular value corresponding to the two entries severally represented by the distance of that point from the front and from one side of the slab. The plate that carries the two traces is placed horizontally on a frame that travels in front of the slab. Two slides move at right angles to this plate, and have microscopes attached to them, that traverse the paper along ordinates having the same abscissa. One of these slides is rigidly connected with a frame on which the slab is able to move from side to side; when this slide is pushed, the frame and the slab together are pushed with it. The other slide gives a sidelong movement of the slab on the frame. Thus the particular point of the slab that corresponds to the values of the two ordinates is brought vertically below a descending rod, and this is caused to drop gently on the surface of the slab by touching a treadle. The vertical space through which the rod descends is consequently the function required. The rod carries a horizontal pricker, with which it makes a dot on a plate held vertically in the same stage that carries the plate on which the two traces are drawn. The slabs can readily be fashioned by instrument-makers who possess the necessary apparatus according to any required tables. They are drilled to the requisite depth at various points, and are afterwards smoothed down.

76b. Rule, with joint, which serves to curve an elastic plate into an arc of the circle, of any radius.

Professor Tchebichef, University of St. Petersburg.

III.—MODELS OF FIGURES IN SPACE.

Collection of Models of Ruled Surfaces, constructed by M. Fabre De Lagrange, in 1872, for the South Kensington Museum.

This collection illustrates the principal types of the class of surfaces which can be traced out in space by the motion of a straight line.

These surfaces, on account of the facility with which they can be constructed and represented, and of the ease with which their intersections can be determined, are of more consequence than any others in the geometry of the Industrial Arts. It is only in small work, which can be put into the lathe, that the class of surfaces of revolution approaches them in respect of general utility. The most important surfaces of all, the plane, the right cylinder, the right cone, and the common screw, belong to both classes.

The representation of the surfaces by means of silk threads is of course only approximate; an approximation of the same character as the representation of a curve by a dotted or chain line, or by a series of right lines touching the actual curve.

The models are constructed with especial reference to the possibility of changing their shape, by moving some of the supports of the strings, by altering the lengths or positions of certain parts, or by converting upright forms into oblique. This possibility of *deformation*, as the process is technically called, greatly enhances the value of the models, by allowing them to represent a much greater variety of surfaces than if they were fixed. They are, however, too delicate to be much pulled about, and, unless they are very cautiously

handled, the strings are apt to become entangled or break. They should never be used except by a person who understands them, and they should not be shifted without some good reason.

Fig. 1.

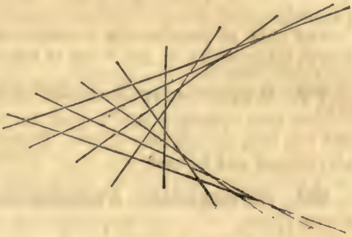


Fig. 2.

Fig. 1 is an example of the first, and Fig. 2 of the second. In both cases, the curve, although not actually drawn, is indicated with sufficient approximation for most practical purposes. Models Nos. 10 and 30 also afford illustrations of the principle exhibited in Fig. 2.

Geometrical drawings of most of the surfaces represented by these models are contained in Bradley's *Practical Geometry* (2 vols., oblong folio, published by Chapman and Hall). Many of them will also be found in the French treatises on practical and descriptive geometry, such as Leroy, Adhémar, Lefebure de Fourcy, De la Gournerie, and in their treatises on *Stereotomy* and *Stone-cutting* (*coupe des pierres*). Many of them are also given in Sonnet's *Dictionnaire des Mathématiques Appliquées.* A catalogue of this collection of models, with an appendix containing an account of the application of analysis to their investigation and classification, was prepared for the South Kensington Museum in 1872, by Mr. C. W. Merrifield, F.R.S. The following descriptions are extracted from this catalogue :—

77. Hyperbolic Paraboloid generated by a single system of right lines.

Two bars, each pierced with holes equally spaced. One bar is fixed, the other swings round an axis, which, moreover, can be inclined at different angles to the fixed bar.

When the bars are parallel the strings indicate a plane. When they are inclined to one another, but still in the same plane, the strings still indicate a plane; but when the bars are not in the same plane, the surface is the hyperbolic paraboloid.

The surface is sometimes called the *twisted plane.* But it must not be supposed that it can be made by bending a plane. On the contrary, when the surface *is* twisted, no two of the strings lie in the same plane, and, therefore, no part of the surface is plane. It can neither be flattened nor made from a plane, without stretching or contraction.

The hyperbolic paraboloid is the natural surface proper for a ploughshare.

78. Hyperbolic Paraboloid.

Two bars, pierced with holes at equal distances, the holes being connected by two different systems of strings. The surface, as well as the arrangement, is very nearly the same as in No. 1, only that there are two paraboloids instead of one. As the movable bar swings round, the paraboloid opens out while the other closes up. If the bars are swung so as to be in the same

plane, one system of strings describes a plane by parallel lines, and the other by lines radiating from a point. If one bar is now turned so as to be end for end, we still get a plane, the set of parallel lines now passing through a point, while the set which previously passed through a point has now become parallel.

The pair of paraboloids intersect in three right lines. There is also a fourth intersection on the "line at infinity."

79. Hyperbolic Paraboloid.

Two bars equally spaced; each turns on an arm perpendicular to itself, and one arm swings on a pillar. These arms can be ranged in one plane, and also turned end for end.

80. Hyperbolic Paraboloid generated by two systems of right lines.

A skew quadrilateral with four equal sides, each pierced with the same number of holes, equally spaced. The model exhibits the double generation of the surface. The plane containing two of the sides turns about hinges connecting it with the plane of the other two sides. By closing or opening this hinge the paraboloid opens out or closes. When completely open, it forms a plane divided into *diamonds.* When completely closed it again forms a plane, but the division is no longer uniform. The strings then become tangents to a plane parabola.

81. Hyperbolic Paraboloid.

A skew quadrilateral turning upon four hinges with parallel axes or pins.

The difference between this and the last is not in the kind of surface or mode of generation, but in the manner of *deforming* the surface. In No. 4 the lengths of the strings alter; while in this model they remain unaltered. Moreover, although the surface flattens in two ways, yet in both ways the strings become tangents to a plane parabola instead of parallel.

This model is well adapted for showing the leading sections of the solid All sections parallel to the pins of the hinges are plane parabolas, which degenerate into right lines when taken also parallel to the brass bars. Any other sections, whether perpendicular to the hinges or inclined to them, give hyperbolas, which degenerate into a pair of right lines when the plane of section is a tangent to the surface.

It may be worth while to remark that there is nothing absurd in the tangent plane to a surface cutting that surface, as a student unaccustomed to those subjects might at first think. On the contrary, when a surface is bent one way in one direction, and the other way in the opposite direction, the tangent plane *must* cut it. In this case, the plane passing through any two intersecting strings is a tangent plane, and evidently cuts the surface along each string.

If we imagine two planes parallel to the hinge pins, and each bisecting a pair of opposite bars, we obtain the *asymptotic planes* of the paraboloid, each of which is the assemblage of the asymptotic lines of the hyperbolas parallel to the principal hyperbolic section. Their being asymptotic has reference to these hyperbolas, and not to the parabolic character of the surface.

82. Hyperbolic Paraboloid.

A skew quadrilateral, with its opposite sides equal in length, and pierced with holes at equal distances.

Nearly similar to No. 5, but differently mounted, and with the sides of different lengths, the alternate sides only being equal. It is virtually a slightly different aspect of the same surface as No. 5.

83. Hyperbolic Paraboloid.

A skew quadrilateral, with all its sides equal, and pierced holes at equal distances.

As far as the curved surface is concerned, the same as No. 5. But the hinges are altered in direction, and the model shows plans and elevations of the right line generators of the surface. The rings also show parabolic sections of the surface.

In consequence of the alteration in the direction of the hinges, the spacing of the inclined bars, although equidistant, is at a different pitch from that of the horizontal bars.

84. Hyperbolic Paraboloid.

A skew quadrilateral, with all its sides equal, and pierced with holes at equal distances. It shows the plans and elevations of the right line generators. The rings show the parabolas of the *principal sections*.

No. 7 represents one quarter of what is shown in No. 8. The upper corners of Nos. 7 and 8 correspond; but the lower corner of No. 7 corresponds with the middle ring of No. 8.

85. Hyperbolic Paraboloid.

A skew quadrilateral, with all its sides unequal. The surface is the same as Nos. 7 and 8, but the proportions and the portion of the surface chosen for representation are different. The quadrilateral base being irregular, the strings alter in length as the surface is deformed by closing the hinges.

86. Hyperbolic Paraboloid.

Skew quadrilateral, pivoting on a single hinge. Intended to show the construction of the parabola connecting two roads which meet obliquely. This construction is used by engineers in laying out roads.

87. Hyperboloid of one Sheet.

Two rings or circles, in parallel planes, are pierced with equally spaced holes. In a certain position the threads give, 1st, a cylinder; and 2ndly, a cone.

The upper ring turns round a pin at its centre. In turning it, the cylinder closes in and the cone opens out, each altering into a hyperboloid of one sheet. We can go on turning the ring until these coincide in one hyperboloid, of which we thus get both systems of generating lines.

If the rings are set on a slope the hyperboloid is elliptic. If the rings are horizontal the hyperboloid is one of revolution.

Sloping one ring, so as not to be parallel with the other, gives rise to some curious ruled surfaces, but these are not in general hyperboloids.

88. Hyperboloid of one Sheet.

Two rings of different radius, in parallel planes, are divided into the same number of equal parts. The smaller and upper ring turns round a pin at its centre. In a particular position of the rings, the threads give two cones. Turning the ring transforms each of the cones into a hyperboloid, and when the two hyperboloids coincide, we get the two systems of right line generators.

The same stand also has a model of a hyperboloid with only one set of strings. By turning the upper ring either way it deforms into a cone; in the one case with its vertex between the rings, and in the other with its vertex at a considerable height above the rings.

Both these can have their upper rings moved along the top bar so as to incline the surfaces. We still get cones and hyperboloids, but it is only

when the rings are horizontal, and centre to centre, that we get surfaces of revolution.

89. Hyperboloid of one Sheet, with its asymptotic cone.

90. Hyperboloid of one Sheet, with its asymptotic cone.

The tangent plane to the cone is also drawn. It meets the hyperboloid in two parallel right lines.

One of these right lines is the line of contact of a hyperbolic paraboloid with the hyperboloid, and the tangent plane is one of the director planes of the paraboloid, both systems of generating lines of which are exhibited.

91. Hyperboloid of one Sheet.

A slight variation from No. 14. The paraboloid only shows one system of right line generators, and the tangent plane is made by parallel instead of radiating lines.

92. Hyperboloid of one Sheet, and its tangent paraboloid.

This shows the transformation of a cylinder and its tangent plane into a hyperboloid and its tangent paraboloid.

93. Conoid, with its director plane. The director curve is a plane curve.

By shifting the position of the brasses the conoids deform into different conoids or other allied surfaces.

94. Conoid, with a director cone. The director curve is of double curvature.

By shifting the position of the brasses the conoids deform into different conoids or other allied surfaces.

95. Conoid, showing both sheets of the surface.

By shifting the position of the brasses the conoids deform into different conoids or other allied surfaces.

96. Conoids. Model showing the transformation of a cylinder into a conoid and back again. Also model showing the transformation of a cone into a conoid and back again. It is to be noticed that the head lines of the two conoids, that is to say, the right line in which the two sheets of each conoid meet, are perpendicular to one another.

The transformation is effected by making the upper semicircle turn through two right angles.

97. Conoids.

Intersection of two equal conoids having a common director plane. The horizontal intersection is a plane ellipse.

98. Conoid, in contact with a hyperbolic paraboloid.

99. Conoids. Two equal circles in parallel planes, divided equidistantly, are connected by threads, so as to form four surfaces.

A cylinder.	A conoid.
A cone.	A second conoid.

The director planes, as well as the head lines, of these conoids are at right angles to one another.

100. Conoids.

Two equal circles in parallel planes are connected by threads so as to form four surfaces.

A cylinder.
A cone.
A conoid.
A second conoid, with its director plane and line at right angles to those of the former.

Same arrangement as No. 23, except that the lower ring is replaced by a plane of section a little higher up. The section gives,—
For the cone, a circle smaller than the upper ring.
For the cylinder, a circle of the same size as the upper ring.
For the conoids, two ellipses turned crosswise.

101. Model exhibiting the simultaneous transformation of a conoid into a cylinder, a cylinder into a conoid, the paraboloid touching the conoid into the tangent plane of a cylinder, and the tangent plane of a cylinder into the tangent paraboloid of a conoid, and reciprocally.

The changes may be arranged as follows :—

From.	Into.
Conoid.	Cylinder.
Tangent paraboloid.	Tangent plane.
Cylinder.	Conoid.
Tangent plane.	Tangent paraboloid.

These changes are all effected simultaneously by one movement, which can be reversed.

102. Model exhibiting the transformation, first, of a conoid into a cylinder; second, of the tangent paraboloid of the conoid into the tangent plane of the cylinder.

103. French Skew Arch (*biais passé*).

The inner drum, of yellow thread, represents this surface. It is a skew surface, with a right line director; and its faces, the planes of the two semicircles, are usually parallel, although the model permits them to be placed obliquely to one another. The horizontal line joining the centres of the two large semicircles is the right line director.

The construction for any one of the generating lines is as follows :—Draw a plane through the right line director at any selected obliquity. It will, of course, give the radii of the outside circles, and the line joining the points at which it cuts the inside semicircles will be a generator of the surface. This line will evidently pass through the director line, because it is in the same plane with it.

The stone or brickwork, the sides of the voussoirs, will be given by the auxiliary plane in question. When the openings are parallel the voussoir joints are therefore plane, and the simplicity thus gained is the chief reason for adopting this form of skew arch. It is usual to take the right line direct or perpendicular to the openings, and symmetrical to them, that is to say, passing through the middle point of the parallelogram of the springing plane.

When the openings are not parallel the voussoir joints shown by the model are deformed into hyberbolic paraboloids. This deformation is, however, very slight, and in practical work would be avoided altogether by adhering to the principle of drawing a plane through the director line.

The opening of the voussoirs is usually determined by dividing the outer semicircle into equal parts.

This form of arch is inconvenient when the obliquity and the length of the barrel are excessive, for the generators are not generating lines of the cylinder containing the opening semicircles, but chords of it, and, therefore, at the middle, falling considerably inside it. The arch, therefore, droops in the middle, and this would be ugly and inconvenient if the proportions were excessive.

104. Staircase Vault for a square wall (*vis St. Gilles carrée*).

105. Staircase Vault. Model for exhibiting some properties of this ruled surface, by showing how it is obtained from the deformation of a cylinder (*douelle de la vis St. Gilles carrée*).

106. Cylinder with Helix and developable Helixoid.

The helix is simply a screw thread. The developable helixoid, shown by the purple threads, is the surface swept out by the right line tangents of the helix. If we consider that each gore can be turned a very little bit about the thread which separates it from the next gore, we see that the surface can be flattened out or developed into a plane, without any crumpling. This happens because every two consecutive generating lines meet one another on the helix. That is why its surface is called developable. Its section by a horizontal plane is the involute of the circle.

The model allows the pitch of the helix to be shortened by lowering the upper plate, and the cylinder can also be inclined. When oblique, however, the curve which replaces the helix is not such a screw thread as can be turned in the lathe.

107. Skew Helixoid.

This surface is described by a right line, which always passes through the axis of a cylinder, and makes a constant angle with that axis. It also passes through a helix or screw thread traced on the cylinder. The model only shows the surface, not the cylinder. The section by a horizontal plane is the spiral of Archimedes. It is the surface of what is known as the screw with a triangular thread.

This is not the commonest form of the skew helixoid; that is best seen on the underside of a screw staircase, or on the driving face of a common screw propeller. In these, two generating lines are at right angles to the axis.

The surface may also be considered as generated by a line which makes a constant angle with a given fixed line, and moves up that line, and at the same time turns round it, at uniform rates.

108. Skew Surface with its tangent paraboloid, capable of transformation into another skew surface while the paraboloid deforms into a plane.

This is (for a certain position of the lower semicircle) a skew surface with a director plane, the plane being vertical. The director curves are: one of them a circle divided equidistantly, the other a semicircle divided so as to keep the strings parallel to the director plane.

109. Intersection of Two Cones having double contact with one another, that is to say, having a pair of tangent planes in common.

The consequence of their having double contact is that their curve of intersection breaks up into two plane ellipses.

The vertices of the cones slide along a rule which turns on a universal joint. See also model No. 38.

110. Common Groin. Intersection of two cylinders having a pair of common tangents. The model may be set square or oblique.

111. Intersection of Two Cylinders, one piercing the other so as to give two separate loops of intersection.

112. Intersection of Two Cylinders, having a common tangent, so as to give a curve having a double point at the point of contact.

113. Intersection of Two Cylinders, neither completely piercing the other, so as to give only one loop of intersection.

114. Intersection of Two Cones, having double contact, along a pair of plane ellipses.

115. Groin. Oblique intersection of two splayed vaults of the same spring.

116. A Pair of Intersecting Planes, which, by pulling the brass ball so as to give simultaneous rotation to the two upper rods, deform into paraboloids first, and then into planes described by radiating strings.

117. Intersecting Cylinder and Plane. By pulling the brass ball the head brasses rotate together, and the cylinder deforms into, first, a hyperboloid, and then a cone, while the plane deforms into, first, a paraboloid, and then again into a plane with radiating lines.

118. A Pair of Intersecting Cylinders on circular bases. By pulling the brass ball the head brasses rotate together, and the cylinders deform, first, into hyperboloids, and then into cones.

119. A Pair of Intersecting Cylinders on irregular bases. By pulling the brass ball the head brasses rotate together, and the cylinders deform, becoming at last cones.

120. Groin.

Model showing the deformation of a common groin, both obliquely, and by splaying the vaults. The model shows not only the

intersection, but the plans of the intersection and of the generating lines.

121. Helix or Screw-thread.

Model showing the transformation of the right line generators of a right cylinder into screw threads of various pitch or obliquity.

The pitch of a screw is the distance between two successive turns, measured in a direction parallel to the axis. When this distance is small, the screw is said to have a fine pitch ; when great, a coarse pitch or high pitch.

Collection of Models Contributed by the London Mathematical Society.

123. Plücker's Models (14) of certain quartic surfaces, representing the equatorial form of complex surfaces.

London Mathematical Society.

At the meeting of the British Association at Nottingham, in 1866, Prof. Plücker read a paper on " Complexes of the Second Order." On this occasion he showed a series of models constructed by Epkens, of Bonn, of which the above are copies made for Dr. Hirst, and presented to the London Mathematical Society.

The following is Prof. Cayley's description of the models, extracted from Nos. 37 and 38 of the Mathematical Society's Proceedings, vol. iii., pp. 281–285, supplemented by a description of models A, B, C, D, E, F, drawn up by Prof. Henrici.

The Society possesses a series of 14 wooden models of surfaces, constructed under the direction of the late Prof. Plücker, in illustration of the theory developed in his posthumous work " Neue Geometrie des Raumes gegründet " auf die Betrachtung der geraden Linie als Raum-elemente," Leipzig, 1869. These, all of them, represent, I believe, equatorial surfaces, viz., eight represent cases of the 78 forms of equatorial surfaces, " deren Breiten-Curven " eine feste Axenrichtung besitzen," vol. ii. pp. 352–363 ; the remaining models, A, B, C, D, E, F, I have not completely identified. I propose to go into the theory only so far as is required for the explanation of the models.

In a " complex," or triply infinite system of lines, there is, in any plane whatever, a singly infinite system of lines enveloping a curve ; and if we attend only to the curves the planes of which pass through a given fixed line, the locus of these curves is a " complex surface." Similarly, there is through any point whatever a single infinite series of lines generating a cone ; and if we attend only to the cones which have their vertices in the given fixed line, then the envelope of these cones is the same complex surface. In the case considered of a complex of the second degree, the curves and cones are, each of them, of the second order ; the fixed line is a double line on the surface, so that (attending to the first mode of generation) the complete section by any plane through the fixed line is made up of this line twice, and of a conic. The surface is thus of the order 4 ; it is also of the class 4 ; the surface has, in fact, the nodal line, and also 8 nodes (conical points), and we have thus a reduction = 32 in the class of the surface.

In the particular case where the nodal line is at infinity, the complex surface becomes an equatorial surface; viz. (attending to the first mode of generation), we have here a series of parallel planes each containing a conic, and the locus of these conics is the equatorial surface.

It is convenient to remark that, taking a, b, h, to be homogeneous functions of (x, w) of the order 2; f, g, of the order 1; and c of the order 0 (a constant); then the equation of a complex surface is—

$$\begin{vmatrix} & y & z & 1 \\ y & a & h & g \\ z & h & b & f \\ 1 & g & f & c \end{vmatrix} = 0;$$

and that, writing $w=1$, or considering a, h, b; f, g; c, as functions of x of the orders 2, 1, 0 respectively, we have an equatorial surface.

A particular form of equatorial surface is thus, $bcy^2+caz^2+ab=0$, or taking $c=1$, this is $by^2+az^2+ab=0$, where a, b, are quadric functions of x.

The surface is still, in general, of the fourth order; it may, however, degenerate into a cubic surface, or even into a quadric surface; the last case is, however, excluded from the enumeration. The section by any plane parallel to that of yz is a conic; the section by the plane $y=0$ is made up of the pair of lines $a=0$, and of the conic $z^2+b=0$; that by the plane $z=0$ is made up of the pair of lines $b=0$, and of the conic $y^2+a=0$; the last-mentioned planes may be called the principal planes, and the conics contained in them principal conics. The surface is thus the locus of a variable conic, the plane of which is parallel to that of yz, and which has for its vertices the intersections of its plane with the two principal conics respectively. And we have thus the particular equatorial surfaces considered by Plücker, vol. ii. pp. 346–363 (as already mentioned), under the form

$$\frac{y^2}{\mathrm{E}x^2+2\mathrm{U}x+\mathrm{C}}+\frac{z^2}{\mathrm{F}x^2-2\mathrm{R}x+\mathrm{B}}+1=0$$

and of which he enumerates 78 kinds, viz.: these are—

1 to 17. Principal conics, each proper.
18 to 29. One of them a line-pair.
30 to 32. Each a line-pair.
33 to 39. Principal conics, each proper, but having a common point.
40 to 43. One of them a line-pair, its centre on the other principal conic.
44 to 61. One principal conic, a parabola.
62 to 73. One principal conic, a pair of parallel lines.
74 to 76. Principal conics, each a parabola.
77 and 78. Principal conics, one of them a parabola, the other a pair of parallel lines.

Model 2. The form of the equation is here,—

$$\frac{y^2}{l^2[(x-\alpha)^2+\beta^2]}-\frac{z^2}{l'^2[(x-\alpha')^2+\beta'^2]}=1$$

viz., the principal conics are one of them a hyperbola, the other imaginary; hence the generating conic has always two, and only two, real vertices, viz., it is always a hyperbola. There are no real lines.

Model 3. The form of the equation is—

$$\frac{y^2}{l^2[(x-\alpha)^2+\beta^2]}+\frac{z^2}{l'^2[(x-\alpha')^2+\beta'^2]}=1;$$

viz., the principal conics are each of them a hyperbola; the generating conic has four real vertices, viz., it is always an ellipse. There are no real lines.

Model 4. The form of the equation is—

$$\frac{y^2}{l^2(x-\gamma)(x-\delta)}+\frac{z^2}{l'^2[(x-\alpha')^2+\beta'^2]}+1=0.$$

The principal conics are one of them an ellipse, the other imaginary; for values of x between γ and δ, the variable conic has two real vertices, or it is a hyperbola; for any other values it is imaginary, so that the surface lies wholly between the planes $x=\gamma$, $x=\delta$. The surface contains the real lines $y=0$, $x=\gamma$, and $y=0$, $x=\delta$.

Model 9. The form of the equation is—

$$\frac{y^2}{l^2(x-\gamma)(x-\delta)}+\frac{z^2}{l'^2(x-\gamma')(x-\delta')}+1=0$$

where, say the values γ, δ, lie between the values γ', δ', the principal conics are each of them an ellipse, the vertices (on the axis or line $y=0$, $z=0$) of the one ellipse lying between those of the other ellipse. The variable conic for values of x between γ and δ has four real vertices, or it is an ellipse; for values beyond these limits, but within the limits γ', δ'—say, from γ to γ' and from δ to δ'—there are two real vertices, or the conic is a hyperbola; and for values beyond the limits γ', δ', the variable conic is imaginary.

There are four real lines ($y=0, x=\gamma$), ($y=0$, $x=\delta$), ($z=0$, $x=\gamma'$), ($z=0$, $x=\delta'$). The surface consists of a central pillow-like portion, joined on by two conical points to an upper portion, and by two conical points to an under portion, the whole being included between the planes $x=\gamma'$, $x=\delta'$.

Model 13. The form of the equation is—

$$\frac{y^2}{l^2(x-\gamma)(x-\delta)}-\frac{z^2}{l'^2(x-\gamma')(x-\delta')}+1=0\,;$$

the values γ', δ', lying between γ, δ; the principal conics are one of them a hyperbola, the other an ellipse, the vertices (on the axis or line $y=0$, $z=0$) of the hyperbola lying between those of the ellipse. The variable conic, for values of x between γ', δ', has two real vertices, or it is a hyperbola; for the values, say, from γ' to γ, and δ' to δ, there are four real vertices, or the conic is an ellipse; for values beyond the limits γ, δ, there are two real vertices, and the conic is a hyperbola. There are the four real lines ($y=0$, $x=\gamma$), ($y=0$, $x=\delta$), and ($z=0$, $x=\gamma'$), ($z=0$, $x=\delta'$). The surface consists of eight portions joined to each other by eight conical points, but the form can scarcely be explained by a description.

Model 32. The form of the equation is—

$$\frac{y^2}{l^2(x-\gamma)^2}+\frac{z^2}{l'^2(x-\gamma')^2}=1\,;$$

viz., the principal conics are each of them a line-pair, the variable conic is always an ellipse.

There are the two real nodal lines ($y=0$, $x=\gamma$) and ($z=0$, $x=\gamma'$), each of these being in the neighbourhood of the axis crunodal, and beyond certain limits acnodal; the surface is a scroll, being, in fact, the well-known surface which is the boundary of a small circular pencil of rays obliquely reflected, and consequently passing through two foca .ines.

Model 34. The equation is—

$$\frac{y^2}{l^2(x-\gamma)(x-\delta)}+\frac{z^2}{l'^2(x-\gamma')(x-\delta')}+1=0$$

where $x=\delta$ is not intermediate between the values $x=\gamma$ and $x=\gamma'$; say the order is δ, γ, γ'. The surface is thus a *cubic* surface; the principal conics are ellipses, having on the axis a common vertex, at the point $x=\delta$, and the remaining two vertices on the same side of the last-mentioned one. The variable conic for values between δ and γ has four real vertices, or it is an ellipse; for values between γ and γ' two real vertices, or it is a hyperbola; and for values beyond the limits δ, γ', it is imaginary. There are on the surface the two real lines ($y=0$, $x=\gamma$) and ($z=0$, $x=\gamma'$). The surface

consists of a finite portion joined on by two conical points to the remaining portion.

Model 40. The form of equation is—

$$\frac{y^2}{l^2(x-\gamma)(x-\delta)}+\frac{z^2}{l'^2(x-\delta)^2}+1=0$$

The surface is thus a *cubic* surface; the principal conics are, one of them an ellipse, the other a pair of imaginary lines intersecting on the ellipse; for values of x between γ and δ, the variable conic has thus two real vertices, and it is a hyperbola; for values beyond these limits it is imaginary, and the whole surface is thus included between the planes $x=\gamma$ and $x=\delta$. There are the two real lines $(y=0, x=\gamma)$ and $(z=0, x=\delta)$.

Taking $l^2=l'^2=1$, the surface is—

$$\frac{y^2}{(x-\gamma)(x-\delta)}+\frac{z^2}{(x-\delta)^2}+1=0$$

which is a *particular* case of the parabolic cyclide.

The equatorial surfaces, not included in the preceding 78 cases, Plücker distinguishes (vol. ii. p. 363) as "gedrehte" or "tordirte," say, as twisted equatorial surfaces, the equation of such a surface is—

$$by^2+2hyz+az^2+ab-h^2=0$$

where $b=\mathrm{F}x^2-2\mathrm{R}x+\mathrm{B}$

$a=\mathrm{E}x^2+2\mathrm{U}x+\mathrm{C}$

$h=\mathrm{K}x^2-\mathrm{O}x-\mathrm{G}$ (or in particular $=-\mathrm{O}x-\mathrm{G}$).

Model A. is such a surface, being a twisted form of Model 9.

Model B. belongs to the case $a=0$; viz., the form of the equation is—

$$by^2+2hyz-h^2=0.$$

The variable conic is a hyperbola, the direction of one of the asymptotes being constant (vol. ii. p. 368).

There are, moreover, (p. 372) equatorial surfaces in which the variable conic is always a parabola, and where there are on the surface four real or imaginary singular lines.

In Model C the singular lines are all four real, but two of them coincide with the nodal line at infinity. Consequently, the variable parabola has its axis in a fixed direction. Its vertex moves along a hyperbola which has one asymptote in that fixed direction. The other two singular lines are on opposite sides of this asymptote and parallel to it. When the plane of the variable parabola passes through one of these lines, the parameter vanishes and changes sign. When it passes through the above-mentioned asymptote, the parabola reduces to the line at infinity and the plane becomes asymptotic to the surface. The latter consists of four parts, two on opposite sides of the asymptotic plane between this and one of the singular lines respectively, the other two extending from the singular lines to infinity.

The remaining three models, D, E, F, represent twisted surfaces. Of the four singular lines two are in each case imaginary. The remaining two are real on the first, coincident on the second, and imaginary on the third. Model D consists, therefore, of three, Model E of two, and Model F of one part.

The models are copies from some constructed by Epkens of Bonn. They were presented to the London Mathematical Society by Dr. Hirst, F.R.S. They have been remounted under the direction of Prof. Henrici, by M. Nolet, a student of University College, London.

Some account of complexes and complex surfaces will be found in Dr. Salmon's Geometry of Three Dimensions (3rd edition, pp. 405, 493, 566, 570).

Professor Cayley's paper is printed in vol. iii. of the London Mathematical Society's Proceedings, pp. 281–285.

123a. Rough Model of Steiner's Surface.

Prof. Cayley.

Steiner's surface is the quartic surface represented by the equation $\sqrt{x}+\sqrt{y}+\sqrt{z}+\sqrt{w}=0$; where the co-ordinates x, y, z, w of a point are proportional to arbitrary multiples of the perpendicular distances from four given planes ; in the model, x, y, z, w are proportional to the perpendicular distances from the faces of a regular tetrahedron, the co-ordinates being positive for a point inside the tetrahedron.

The surface may be regarded as inscribed in the tetrahedron, touching each face along the circle inscribed in the face. The general form is that of the tetrahedron with its summits rounded off, and with the portions within the inscribed circles scooped away down to the centre of the tetrahedron, in such wise that the surface intersects itself along the lines drawn from the centre to the mid-points of the sides (or what is the same thing, the lines joining the mid-points of opposite sides). The lines in question produced both ways to infinity are nodal lines of the surface, but as regards the portions outside the tetrahedron, they are acnodal lines, without any real sheet through them ; and these portions of the lines are not represented in the model.

The sections by a plane parallel to a face of the tetrahedron are trenodal quartics, which (as the position of the plane is varied) pass successively through the forms :

1. Four acnodes.
2. Trigonoid, with three acnodes.
3. Tricuspidal.
4. Trifoliate, with three crunodes, cis-centric.
5. Do. with triple point at centre.
6. Do. with three crunodes, trans-centric.
7. Twice-repeated circle.

The three nodes being in each case the intersections of the plane by the nodal lines, and the twice-repeated circle being the circle inscribed on the face of the tetrahedron.

123b. Model of a Cubic Surface.

Prof. O. Henrici, F.R.S.

The equation to this surface is $xyz=k^3(x+y+z-1)^3$. There are 3 biplanar nodes as shown on the model. The 27 straight lines on the surface are all real, but coincide 9 to each with the 3 black lines drawn on the model.

123c. Sylvester's Amphigenous Surface, a surface of the ninth order. *Prof. O. Henrici, F.R.S.*

This surface is connected with the reality of the roots of equations of the ninth degree.

124. Models. A series illustrative of Plücker's Researches in Geometry of Three Dimensions. *Prof. Hennessy, Dublin.*

125. Diagrams (48) showing the Fundamental Principles of the exhibitor's "Organic Geometry of Form."

Prof. Franz Tilser, Prague.

The above work demonstrates the necessity for a reform in geometry, and furnishes the necessary basis for establishing a new system adapted to satisfy the requirements of an exact science. To the above are added 7 "Paragram" Tablets, representing in natural organic connexion a synopsis of the principal elements to be observed in every graphical representation.

126. Model of the ruled cubic surface called the **Cylindroid**.
Dr. Robert S. Ball, LL.D., F.R.S.

This surface was discussed by Plücker in connexion with the theory of the linear-complex. The kinematical and physical significance of the surface will be found in the "Theory of Screws." The equation of the surface is $z(x^2+y^2)-2mxy=0$.

127. Models (6) illustrating the relative bases of Descriptive Geometry and the Organic Geometry of Form.
Prof. Franz Tilser, Prague.

128. Drawings. A collection, executed by the Students of the Bohemian Polytechnic Institute, illustrative of the instruction received in the subject of Organic Geometry of Form.
Prof. Franz Tilser, Prague.

129. Two specimens of Stereometrical Wire Models, with letters on cork.
Prof. J. Joseph Oppel, Frankfort-on-Maine.

130. Two specimens of Trigonometrical Wire Models, with letters. *Prof. J. Joseph Oppel, Frankfort-on-Maine.*

131. Two specimens of Stereometrical Models of Wood, with letters.
Prof. J. Joseph Oppel, Frankfort-on-Maine.

The auxiliary lines, diagonals, &c. are distinguished by wires of different colours or thicknesses. They are in many cases movable, so that the perfect figure can be constructed before the eyes of the pupil.

Auxiliary planes are also distinguished by their colour. The angular points are provided with metal pins, to which letters on cork plates can be attached, so as to be turned upright towards the observer.

These models have proved highly serviceable for instruction during the past 20 years.

132. Large Model of an Ellipsoid, of white cardboard, on a turned stand. *Prof. Dr. A. Brill, Munich.*

133. Cardboard Models of Surfaces of the second order, on frames. Made up of circular sections. The sections are attached to each other. *Prof. Dr. A. Brill, Munich.*

This collection of models consists of :—

1. An **Ellipsoid** having 20 circular sections;
2. An **Ellipsoid** having 30 circular sections;
3. A **Hyperboloid** of one sheet;
4. A **Hyperboloid** of two sheets;
5. An **Elliptic Paraboloid**;
6. A **Cone** in two sheets; and
7. A **Hyperbolic Paraboloid.**

141. Series of Cardboard Models of Surfaces, of the second order, in a cardboard box. The sections are not attached to each other. *Prof. Dr. A. Brill, Munich.*

These models are distinguished from those in common use by their mobility, by means of which each one represents not only a single ellipsoid or hyperboloid, but also a host of surfaces of one or the other kind. For when the angle of inclination of the circular sections is altered, in a direction easily recognised by pressing or drawing out the model, there will be obtained a simple but infinite system, the individual forms of which can be converted from a flat figure through gradually-changing solid bodies to just such another figure with a different relation of axes, without, however, losing its properties.

The equations representing these systems of surfaces are in rectangular co-ordinates :—

For central surfaces :

$$\frac{x^2}{a^2}+\frac{y^2}{\cos^2\psi}\left(\frac{1}{a}-\frac{1}{k}\right)+\frac{z^2}{k\sin^2\psi}=1, \text{ or } = 0 \text{ (cone).}$$

For the elliptic paraboloid :

$$\frac{x^2}{a^2}+\frac{y^2}{a^2\cos^2\psi}-\frac{2z}{k\sin\psi}=0$$

Where 2ψ is the inclination of the circular sections, and a and k are real constants. From the first equation it appears that among the series of ellipsoids there will always be a sphere.

142. Model of a Surface of the third order, made in plaster of Paris, with 27 real right lines.

Prof. Dr. Christian Wiener, Carlsruhe.

The construction of the model is described on a placard fixed to the model.

143. Model of the same surface of the third order, in discs of card-board, with 27 real right lines.

Prof. Dr. Christian Wiener, Carlsruhe.

144. Poinsot's Star Polyhedra. *Max Doll, Carlsruhe.*

These models show the **star dodecahedron** with 20 points, the **star dodecahedron** with 12 points, the **icosahedron** and **dodecahedron**.

148. Curvilinear centre surface of the Ellipsoid, in four separate pieces. Proportions of the axes of the ellipsoid, 3 : 4 : 5. *Ludwig Lohde, Berlin.*

149. Dupin's Cyclide, according to the calculation of Professor Kummer, at Berlin. Model 0·094 m. diameter.

(*See* Monatsbericht der Akademie der Wissenschaften zu Berlin, 1863, pp. 328 and 336.) *Ludwig Lohde, Berlin.*

150. Kummer's Cyclide. *Ludwig Lohde, Berlin.*

151. Minimum-surface in a recurring number of tetrahedral surfaces.

(Submitted to the Berlin Academy of Sciences by Professor Kummer, on the 6th April 1865.) *Ludwig Lohde, Berlin*

152. Maximum of Attraction of the Earth's Surface.
Ludwig Lohde, Berlin.

153. A Geometric Body, executed in plaster of Paris, called "**Podoid;**" a transcendental curved surface, which is determined by the variable parallel co-ordinates μ, ϕ, and κ, whose equation represents the elliptic function

$$\mu=\int_0^\phi \frac{d\varphi}{\sqrt{(1-\kappa^2\sin^2\varphi)}}=\mathrm{F}(\varphi,\kappa)$$

The construction in plaster of Paris embraces the limits $\kappa=+1$ to $\kappa=-1$ and $\varphi=0$ to $\phi=\pi$.

154. The same **Podoid,** executed on a smaller scale, embracing the limits $\kappa=+1$ to $\kappa=-1$, $\varphi=0$ to $\varphi=2\pi$.
Prof. Dr. Edward Heis, Münster, Westphalia.

155. Right double circular Cone, of white wood.
Prof. Borchardt, Berlin.

On the one sheet of the double cone are shown, by sections, the circle, the ellipse, and the hyperbola; on the other, the circle, the parabola, and the corresponding hyperbola. The model takes to pieces at the sections.

156. Elliptic Cone, of white and brown wood.
Prof. Borchardt, Berlin.

On the oblique cone are shown the two circular sections, and the elliptic, hyperbolic, and parabolic sections. At the sections of the ellipse and parabola the model takes to pieces; the other sections are shown by the lines defined by the dark and light wood.

157. Ruled Surface of the fourth degree.
Prof. Borchardt, Berlin.

This model represents a surface of the fourth order determined by the equation—

$$\frac{3x^2}{(z-a)^2}+\frac{3y^2}{(z+a)^2}=1.$$

The surface has two pairs of right lines, between which lies a finite sheet of the surface as shown on the model, whilst beyond each pair of right lines there extends a second and third infinite sheet of the surface. Every horizontal section of the surface is an ellipse. Of these are shown the circular section corresponding to $z=0$, and the two ellipses corresponding to $z=\pm\frac{a}{2}$. The model can be taken to pieces at each of these sections.

158. Rectangular Parallelopiped, intersected by a skew surface. *Prof. Borchardt, Berlin.*

159. Right Circular Cylinder, with spiral surface intersecting it. *Prof. Borchardt, Berlin.*

These five models, Nos. 155–159, are executed by the late *Ferd. Engel*, known from the drawings, which he has furnished to *Prof. Schellbach's* "Darstellende Optik."

160. String Model, representing a hyperboloid of one sheet. On it are shown the principal ellipse, the asymptotic cone, and a tangential surface, in threads of different colours.

Dr. Wiecke, Cassel.

This model represents by means of strings (kept tight by springs) of different colours the hyperboloid of one sheet and its principal auxiliary surfaces. The two sides of the surface are shown by the green and red strings respectively; the principal ellipse is given by the points at which the strings pass through the network stretched on the frame; the asymptotic cone is shown by yellow, and a tangent plane by white strings.

161. Model in plaster of Paris, representing the eighth part of the former with a developable normal surface, lines of curvature and edge of regression. *Dr. Wiecke, Cassel.*

This plaster model represents the eighth part of the surface of an hyperboloid of one sheet; it is constructed on the principal ellipse, and shows the principal axes. It is also attempted to demonstrate on this hyperboloid the lines of curvature of the first and second kind, first investigated by Monge. On this account the hyperboloid is bounded on the side opposite to the principal ellipse by a normal surface of which the directrix is one of the lines of curvature of the first kind. The normals are drawn in this normal surface, and produced to meet in the edge of regression, which with two of the normals will then become the boundaries of the normal surface.

161a. Collection of 45 geometrical solids in cut crystal, for purposes of demonstration. *Madame Wentzel.*

162. Intuitive Method of Projection, by movable planes. Cardboard models (19), practically illustrating problems of space.

Frère Memoire Piron.

162a. Open Frames containing **Photographs** for teaching by projection. *T. and A. Molteni, Paris.*

162b. Projection Apparatus, polyorama for superposed images. *T. and A. Molteni, Paris.*

IV.—REPRESENTATION OF FIGURES IN SPACE BY MEANS OF DRAWINGS ON A PLANE.

163. Diagrams and Models, illustrative of **Descriptive Geometry,** executed by the Frères de la Doctrine Chrétienne, of Paris. *Professor Pigot, Dublin.*

164. Drawings, executed in the college by the students, showing the nature of the courses of **Descriptive Geometry** and engineering. *Professor Pigot, Dublin.*

165. Specimens of a series of **simple folding models** for illustrating the various propositions in **Descriptive Geometry.**

Prof. Osborne Reynolds.

These are specimens of a series of models designed for illustrating the various propositions in descriptive geometry. They are especially designed for lecturing purposes, for which their simple construction, and the capability which they possess of folding into small compass, well adapts them.

166. Stereoscopic Figures, for demonstration and use in the study of stereometry and spherical trigonometry. Edited by Julius Schlotke. *L. Friederichsen and Co., Hamburg.*

167. The principal Problems of Descriptive Geometry, represented by stereoscopic figures, by Julius Schlotke. *L. Friederichsen and Co., Hamburg.*

168. Stereoscopic representation of a number of the most important crystals, their combinations, &c., by Julius Schlotke. *L. Friederichsen and Co., Hamburg.*

The stereoscopic figures of Schlotke are as yet the only ones of their kind in use for illustrating instruction in descriptive geometry and crystallography, in polytechnic and other higher educational institutions, where they are much appreciated.

More particularly the division of crystallography is recommended, as it renders unnecessary the usual expensive models, and, better than those models, demonstrates the combinations and growth of crystals.

A stereoscopic apparatus is placed near the objects.

SECTION 3.—MEASUREMENT.

West Gallery, Ground Floor, Rooms H. K.

I.—SPECIAL COLLECTIONS.

Collection of Standard Measuring Apparatus contributed by the Standards Department of the Board of Trade.

A.—*Comparing Apparatus, &c. for Standard Weights and Measures.*

169. Comparing Apparatus for End-Standards of length. Used by Mr. Sheepshanks in the work of the Commission for Restoration of the Imperial Standards, 1844–1850. Constructed by Troughton and Simms.

The standard and compared end-bar are placed successively on the **V** supports, with one defining end in contact with the left hand stud and the other defining end with the suspended gravity-piece interposed between it and the right hand stud. The last-mentioned stud is to be gently pressed forward by the micrometer screw until it just holds up the gravity piece in position, thus ensuring constant pressure for each observation. The readings of the micrometer being taken, the difference of the two readings shows the difference in length of the two end bars to less than 0·0001 inch, which is the value of one division of the micrometer.

To obtain results with scientific precision the temperature of the measuring axis of each bar during the comparison should be known, as well as its rate of expansion. The temperature and length of the bar connecting the two studs and of the metal of the apparatus should also be constant.

170. Two Lever Frames, with rollers for supporting standard bars. Such lever frames are used for supporting all the Imperial Standard yards made by the Commission for restoring the Standards. Constructed by Troughton and Simms.

Each bar is supported on the eight rollers of the two lever-frames, which are placed symmetrically under the bar, so that the upward pressure of each of the eight different rollers is necessarily equal, and the length between the defining points of the bar is not altered by its flexure. Equal intervals of supports $= \frac{\text{length of bar}}{\sqrt{n^2-1}}$, where n is the number of supports.

171. Double Micrometer Microscope for comparing the smaller subdivisions of standards of length. Constructed by Troughton and Simms.

It has a moveable eye-piece with a double lens, sliding upon a horizontal plate, and two micrometers ; and has two object-glasses, each with a double

lens, sliding on a horizontal plate parallel to the other plate. The measuring field is about two centimetres in extent, or a little less than 1 inch. Value of one division of each micrometer = 0·00003097 inch, or 0·0007866 millimetres.

172. Apparatus for determining the Expansion of Standard Bars. Constructed by Troughton and Simms.

The trough containing the steel bar with projecting points, distant 1 yard and 1 metre, is filled with melting ice to secure constant length at the temperature of 0° C. The standard bar is placed in the lower trough, with two standard thermometers, and is raised gently against the points. Their impression shows the constant length on the bar at its noted temperature in ordinary air. Next fill the lower trough with melting ice, and take impressions to show the constant length on the bar when at 0° C. Then fill the lower trough with water, and raise to boiling point, or other less high temperature, by the heat from the gas jets underneath, and take impressions to show the constant length on the bar when at 100° C., &c. From the difference of these lengths accurately measured under micrometer microscopes, the rate of expansion of the bar is deduced.

173. Large Callipers for measuring diameter and depth of cylindrical or other measures. Constructed by Troughton and Simms.

These are made on the same principle as the instruments used for measuring shot and the bore of guns at Woolwich. They measure diameters up to 24 inches and within 0·001 inch by the aid of a vernier.

174. Model of Sub-divided Yard with comparing apparatus, for the use of local inspectors of weights and measures. Constructed by Troughton and Simms.

The tested yard measure is placed with its zero defining line immediately under that of the standard. By running the eye-piece along the upper guide bar, each defining line is accurately compared and differences determined to less than 0·01 inch by means of the small supplementary sub-divided inch measure placed also under the eye-piece. This apparatus is described and illustrated in Appendix III., 7th Annual Report of Warden of the Standards, 1873.

175. Spherometer for measuring spherical curves, with true gun-metal plane. Used for measuring the flexure of the middle of the glass disc placed upon the Imperial Standard bushel. Constructed by Troughton and Simms.

When the horizontal plane is made to rest with its three triangular flattened points upon the true plane, the central screw with its micrometer head is accurately adjusted in the same plane, and its reading noted. By substituting for the plane the surface to be tested, its convexity or concavity is determined from the difference of the reading of the micrometer, either − or +. Value of one revolution of the screw = 0·01 inch, and of one division of the micrometer = 0·0001 inch. By interposing a bright beam of light between the point of the screw and the surface tested, and by estimation of 0·1 division, accurate measurements have been made to 0·00001 inch. This instrument is described in Appendix X., 6th Annual Report of Warden of the Standards, 1872.

176. Cathetometer for vertical measurements. Constructed by Troughton and Simms.

For example, for accurately reading a barometer or manometer: place the cathetometer at a convenient distance, and adjust the cobweb line of the upper telescope to the level of the mercury in the glass tube, and that of the lower telescope to the level of the mercury in the reservoir. The difference of the two readings on the graduated scale of 42 inches gives the length of the column of mercury to 0·001 inch, by aid of the vernier.

177. Stereometer for ascertaining the density of bodies by determining their volume. Constructed by Troughton and Simms.

This instrument was invented by M. Say (Annales de Chimie, t. xxiii. p. 1, 1797), for determining the specific gravity of gunpowder, and was used with some improvements by Professor W. H. Miller (*See* Phil. Trans. 1856, part iii. p. 800.) for determining the density of the platinum *Kilogramme des Archives*, during his work of restoring the imperial standard pound. The solid body tested is placed in the receiver communicating with the upper end of a vertical glass tube, the lower end of which communicates with that of a second glass tube having its upper end open to the air. The body should nearly fill the receiver, which is screwed up air-tight in its place. Mercury is poured into the second tube, and can be discharged by a stopcock at its lower end. Differences in the relative height of the mercury in the two tubes are noted as indicating the volume of compressed air under the two conditions by means of the cathetometer, when the body is in the receiver and when it is removed. The volume of the body is deduced from the volume of the mercury contained in the tube between the different heights noted.

178. Balance of new construction oscillating with steel springs. This has been recently constructed by Mr. Oertling from a design of Mr. Artingstall.

The principle is, that, instead of the beam and pans being suspended on knife-edges, thin elastic steel springs are used, and adjustments of knife edges from time to time are thus avoided. Its advantages are like those of Steinheil's silk ribbon balance in its simple construction and durability, where extreme scientific accuracy is not required; but it appears to be wanting in the sensibility and stability requisite for a balance of precision.

179. Model Kit of Apparatus for Local Inspectors of Weights and Measures. Constructed by Mr. Oertling.

This portable collection of all the necessary apparatus for comparing imperial weights and measures has been taken from the *Nécessaire des Vérificateurs*, employed in France for verifying metric weights and measures, with a view to its adoption in this country. It includes a Septimal Balance by means of which a weight of 56 lbs. is compared against 8 lbs., the sum of the standard weights.

180. Experimental Gasholder for determining the internal temperature. Constructed by Messrs. Wright & Co.

By raising and lowering the bulb of the thermometers, the tubes of which are made to slide through the top of the gasholder, the temperature of the gas or air at various heights inside the bell can be read off through the glass side, and the mean temperature determined.

181. King's Pressure Gauge, showing mechanical pressure of gas or air. Constructed by Mr. Sugg.

Standards Department, Board of Trade.

The amount of the mechanical pressure of gas or air contained in a gasholder is shown by this pressure gauge, when it is put in communication with the gasholder by an air-tight tube. The surface of the water in the cistern of the pressure gauge is depressed by the force of the gas or air, and alters the level of a metal cup floating on it. A cord is attached to the float, and passes over a pulley, the spindle of which, aided by friction rollers, carries a pointer moving on a graduated dial, and thus indicates the amount of pressure in hundredths of an inch.

Specimens of Standard Weights and Measures.

182. Copy of Standard Weight, 112 lbs., of Queen Elizabeth.

One of two similar bronze weights deposited in one of the old Treasuries of the Exchequer, and fully described in App. IV. to the 7th Annual Report of the Warden of the Standards.

183. Gilt Steel Yard, line measure, of the same form as the imperial standard yard. Constructed by Troughton and Simms.

Well-holes are cut down to the mid-depth of the bar, where the defining lines are cut upon gold studs, thus , the measure being taken at the middle portion of the central transversal line, intercepted between the two longitudinal lines. These lines, including the two transversal guide lines, one on each side of the defining line, are 0·01 inch apart.

184. Steel Yard End Measure, showing the form of end-standard yard adopted by the Standards Commission. Constructed by Troughton and Simms.

The form of the defining ends is that of a spherical surface, whose centre is the centre of the division line in the middle of the bar's length. The material of the defining end is a highly polished plug of agate, shrunk into a slightly conical hole at the end of the steel bar.

185. Steel Foot End-Measure. Constructed by Troughton and Simms.

186. Two Steel 6-inch End-Measures, one finished and one unfinished. Constructed by Troughton and Simms.

187. A 10-Foot Measuring Rod, of pine wood, bound with brass. Constructed by Troughton and Simms.

188. A 3-Foot Measuring Rod, of pine wood, bound with brass. Constructed by Troughton and Simms.

189. One lb. Avoirdupois Weight, of gun-metal, electro-plated with nickel.

Constructed as an experiment of coating brass or bronze with unoxidisable metal. Oxidation, however, is found to occur at points on the surface of the bronze under the nickel coating.

190. One Kilogram Weight, of gun-metal, nickel-plated.

191. Set of Glass Avoirdupois Weights, from 7 lbs. to 1 oz., made experimentally of green bottle glass, not subject to hydroscopic influences. The larger weights adjusted with lead shot.

192. Set of Metric Weights, from 1,000 grammes to 1 gramme. Constructed by Salleron, Paris, of opaque glass, adjusted with mercury to the density of brass weights, and hermetically sealed.

193. Specimen of an Enamelled Iron Weight of 56 lbs., made to resist oxidation, by De Grave, Short, and Co.

194. Specimen of a Patent Brass-cased Iron Weight of 14 lbs.

195. Section of a Patent Brass-cased Iron Weight of 14 lbs., showing mode of construction.

196. Copy of Standard Cubic Foot nickel-plated, with filling apparatus. Constructed by G. Glover & Co.

This is a copy of the standard cubic foot bottle, the primary unit from which the gas-measuring standards were derived. It was verified by weighing its contents of distilled water = 62·321 pounds avoirdupois, according to Sir G. Shuckburgh's determination of the weight of a cubic inch of water. It is used as a direct transferrer of a cubic foot of gas or air, which is driven out from it by raising the cistern and thus introducing water from underneath up to the defining line of a cubic foot. By this arrangement, the nearly undisturbed surface of the water is carried upwards and gradually through the entire height of the bottle, without risk of forming air bubbles.

197. Copy of five cubic feet Gas-measuring Standard, made of anti-corrosive metal, by G. Glover and Co., with scale of capacity graduated in feet and minute fractional parts.

The bell is equipoised when at various depths of its immersion in the water of the cistern by a balance, a portion of which hangs from a cord working in a groove in the circumference of a cycloidal wheel, and attached to the axis of the wheel from which the bell is suspended.

198. Copy of a Standard Test Dry Gas Meter, with testing table. Constructed by G. Glover & Co.

Such test gas meters are authorised to be used for testing stationary meters, where the larger gas measuring standards cannot conveniently be used. The accompanying testing table shows it fitted with thermometers and pressure gauges, and with stand pipes for outlet and inlet communications.

199. Model of a Petroleum Testing Apparatus, for ascertaining the temperature at which its inflammable vapour ignites. Designed by T. W. Keates, Esq., and proposed as a standard for use in accordance with authoritative uniform regulations. Constructed by How & Co.

200. A Brass Scale of 41 inches, divided into tenths, and of a metre divided into millimetres ; both scales at 62° Fahr. Constructed by Dollond, and now the property of Mr. Petrie.

This possesses some scientific interest, having been compared several times with Shuckburgh's scale by Capt. Kater. He found in 1830, and again in 1831, that 36 inches of the scale = 35·99893 inches of the imperial standard yard, afterwards destroyed in 1834; and assuming the scale of inches to be perfectly correct, that the metre = 39·37045 inches.

Compared at the Standards Office in February 1876, with the bronze official yard, which has a standard metre at 0° C. marked on the same bar. From the mean of six comparisons, 36 inches of the scale = 35·99961 inches of the imperial standard yard, and the metre = 0·999684 metre, being 0·316 millimetre less than the *Mètre des Archives* at the normal temperature of 0° C.

SET OF OLD STANDARD MEASURES LENT BY THE MAYOR AND CORPORATION OF THE CITY OF WINCHESTER.

201. A very old Steelyard Weight, date unknown. Found at Hyde Abbey, Winchester.

202. Set of Standard Troy Weights, from 256 oz. to 1 oz., of Queen Elizabeth. Dated 1588, being the year in which she granted a charter to the city.

203. Set of Standard Weights (avoirdupois), 56 lbs., 7 lbs., 8 lbs., 2 lbs., 1 lb., of Queen Elizabeth, dated 1588, being the year in which she granted a charter to the city. From the Muniment Room, Winchester.

204. Standard Weights (56 lbs., 28 lbs., 14 lbs., and 7 lbs.). Supposed to be of the date of Edward III. From the old Muniment Room over the West-gate, Winchester.

205. Standard Yard Measure. Henry VII. From the Muniment Room, Winchester.

206. Standard Quart and Pint of William III. Dated 1700. From the Muniment Room, Winchester.

207. Standard Gallon, Quart, and Pint of Queen Elizabeth, dated 1601. From the Muniment Room, Winchester.

208. Standard Winchester Bushel, given to the Corporation by Henry VII. in the year 1487.

209. Standard Winchester Gallon, given to the Corporation by Henry VII., in the year 1487.

Set of Measuring Instruments contributed by Sir J. Whitworth & Co., Manchester.

210. Box of Standard Lengths, of end measure, 1 inch to 12 inches.

These are standard lengths of end measure, and are used for adjusting the measuring instrument to any required length, and for any other purpose where a standard of end measure is required.

211. Measuring Instrument, graduated to measure one millionth of an inch.

The power of measurement is one of the most important elements in practical mechanics, and can only be obtained in the highest degree by means of the true plane.

The value of a machine, when made of the best material, depends on truth of surface, and the proper difference of size between the external and internal diameter of the various parts that have to work together; when experience has determined this, accurate measurement comes into play, and enables these exact differences of size to be carried out.

One of the principal uses of the measuring instrument is to ensure extreme accuracy in the manufacture of difference gauges. The principle is that of employing the sense of touch instead of sight.

In order to measure end measure with the utmost accuracy a thin flat piece or bar is introduced, baving its two sides made true planes; this piece is called the gravity piece, and is placed between the end of the piece to be measured (which is also made a true plane) and one of the end surfaces of the machine, so as just to allow it to fall by its gravity; by bringing the planes into closer contact, even the one millionth of an inch, the gravity piece will be suspended—friction overcoming gravity.

212. Measuring Machine, graduated to measure one ten thousandth of an inch.

This instrument was designed by Sir Joseph Whitworth for use in the workshops where high-class work is carried on.

It is graduated to read to one ten thousandth of an inch, but one forty thousandth of an inch can readily be measured by it.

The principle of this instrument is the same as that of the one previously described.

213. Difference Gauges, *i.e.* gauges differing in size one from the other by very minute quantities; they are essential to enable a workman to work to extreme accuracy.

To illustrate the importance of small differences in size the internal gauge here exhibited is ·5, while the two external gauges or solid cylinders are respectively ·5 of an inch and ·4998 of an inch; the latter is one five thousandth of an inch larger than the former; the one fits tightly, the other appears not to fit at all.

Without the aid of difference gauges it would have been impossible to have produced rifle barrels so exactly similar that the shooting of one is not distinguishable from another as regards their relative accuracy.

214. Sample of Gauges, external and internal, in general use.

Gauges, one inch external and internal, as made for use in the workshop.

These gauges, which are in general use, are made from $\frac{1}{10}$th of an inch to 6 inches in diameter.

215. Measuring Instrument for the Bores of Guns. Differences of one ten thousandth of an inch can be measured with this instrument.

This instrument was designed by Sir Joseph Whitworth to measure the expansions of the bore of a gun, due to the explosion of the charge of powder, and to ascertain what strain a gun would stand before permanent alteration took place.

The instrument is moved by hand along the bore of the gun, and the projecting feelers are connected to a micrometer at the end of the bar.

Differences of one ten thousandth of an inch are quite perceptible.

216. Standard Screw Gauge of Whitworth thread.

This gauge is to show the form of the Whitworth standard thread. The two cylindrical parts give the exact diameter of the top and bottom of the screw threads in universal use; the angle is 55° rounded off $\frac{1}{6}$th of its depth.

217. New Hexagonal Surface Plates designed to insure that the surfaces remain true under different conditions.

The original surface plate first exhibited by Sir Joseph Whitworth at Glasgow in 1840 was rectangular, and ribbed on the under side in such a way as to allow of being supported on three points.

Two handles, one at each end, were fastened to the plate for lifting, and from them it was suspended when about to be applied to the work in hand.

When rectangular surface plates of large size were suspended a straining took place, and they were no longer as true as when supported on the three points. The new hexagonal surface plate, besides being supported on three points, is also suspended from the same three points, and remains true when so suspended.

The surface remains true under different conditions: a 30-inch plate was heated to 200 degrees, and at that temperature did not vary the 1,000th of an inch.

The true plane is the foundation and source of all truth in mechanism.

Apparatus used by Dr. Joule, F.R.S., for ascertaining the Mechanical Equivalent of Heat.

218. Revolving Electro-magnet, used in 1843 for ascertaining the **Mechanical equivalent of Heat.**

Part of the apparatus used in 1843 for the determination of the mechanical equivalent of heat: viz., a revolving piece, holding a glass tube filled with water, and containing an electro-magnet. This worked between the poles of a powerful magnet; and the heat evolved by the rotating electro-magnet was measured by the rise of temperature of the water. In this manner the quantity of heat lost by the surface was ascertained when the machine worked as an engine; and, on the other hand, the quantity of heat produced when work was done on the machine was also measured; 833 ft. lbs. was the mechanical equivalent of a degree Fahr. in 1 lb. of water, as determined by these first experiments.

219. Calorimeter, containing a **revolving agitator.** This was employed in the experiments on the heat evolved by the friction of water, made in 1849. The equivalent arrived at was 772 ft. lb.

223. Paddle Apparatus, by means of which Dr. Joule determined the dynamical equivalent of heat. Described in Philosophical Transactions for 1850, page 65. *Sir William Thomson.*

220. Cast-iron Vessel, containing **Friction Disk,** to revolve under mercury. Used in 1849 to determine the mechanical equivalent of heat from the friction of cast-iron against cast-iron. The equivalent arrived at was 775 ft. lb.

221. Electro-magnet consisting of a broad plate of half-inch iron, having a bundle of copper wires coiled round it. Employed in the first determination of the mechanical equivalent of heat.

222. Apparatus for determining the temperature of water at its maximum density.

Used in the experiments on atomic volume and specific gravity by Playfair and Joule (Memoirs of the Chemical Society, vol. iii., 1846). It consists of two tall vessels, connected together by a stop-cock at the bottom, and a trough at the top. A minute difference of the temperature of the water in one of the vessels from that of the maximum density, determines a flow through the trough to the vessel still nearer the temperature of maximum density. The temperature of maximum density of water was thus shown to be 39·1.

II.—MEASUREMENT OF LENGTH.

A. Standard Scales.

224. Brass Standard Scale (Bird's). Date about 1750. *Royal Society.*

225. Brass Standard Scale (Sir G. Shuckburgh's). *Royal Society.*

227. Standard Scale, in porcelain, showing the relations of modern British and ancient Great Pyramid inches. *Prof. Piazzi Smyth.*

This scale was prepared to order by M. Casella, of London. It exhibits side by side 25 modern British inches and the same number of ancient Great Pyramid inches, similarly subdivided.

The 0 divisions of both sets of inches coincide at the left hand exactly, but from thence the gradual growth of the difference of 0·001 of an inch per inch in favour of the Great Pyramid scale may be traced, until at the 25th inch the difference amounts to 0·025 of the British inch. At that point, however, it is to be noted that 25 Great Pyramid inches are just one 10 millionth of the earth's semi-axis of rotation, or the nearest earth commensurable and scientific unit ever yet proposed as a standard of length.

228. Standard Five-Inch Scale, in smoky agate, for microscope sight. *Prof. Piazzi Smyth.*

The material, which came from Brazil, and was worked up and divided to order by M. Jules Salleron, Paris, was chosen as being a natural product of almost infinite age, and therefore settled condition, harder than steel and utterly unoxidisable. The particular standard length adopted is shown for microscopic sight. It depends not on one pair only, but on 20 available pairs of lines, each five inches apart, drawn with a fine diamond point, and is intended to typify both one fifth of the sacred cubit of Israel and one 50 millionth of the earth's semi-axis of rotation.

229. Standard Five-Inch Scale, in white chalcedony, for microscope sight. *Prof. Piazzi Smyth.*

This material, which came out of some ancient Roman palace, is chosen for the same reasons as that last described. The scale is divided on the same system.

230. Standard Five-Inch Scale, in red porphyry, for microscope sight. *Prof. Piazzi Smyth.*

This material came from an Imperial Roman palace to which it had been taken under the Cæsars from some far more ancient Egyptian temple. It was originally quarried by the Egyptians of 3,500 years ago in the rich porphyry district between Thebes and the Red Sea, and it has been adopted for the same reasons as the preceding examples, and the scale is divided on the same system.

232. Standard of Length, derived from the earth's polar axis, which is unique and common to all terrestrial meridians. *Professor Hennessy.*

This standard is a bronze bar, which, at 15° of temperature centigrade, is equal to the fifty millionth part of the earth's axis. This standard was first proposed by Professor Hennessy, and a similar standard was afterwards suggested by Sir John Herschel.

233. Steel Chain, of fifty links, whose total length is the millionth part of the earth's axis, or very nearly 500·5 English inches. It is nearly equal to the half chain of two perches in Irish plantation measure. *Professor Hennessy.*

235. Standard Yard Measure, German Silver, with one chamfer divided to inches and 10ths. Temperature 60° Fahrenheit. *Elliott Brothers.*

239. Steel Tape Measure, 66 ft. For testing tapes, divided to feet and inches on one side and links on the other. *Elliott Brothers.*

244. Scales, of boxwood, showing the equivalents of English and Foreign measures of length. *Aston & Mander.*

The bevel edged set square side is used to show the divisions coinciding; and the equivalent values of English and Foreign measures of length may thus be readily obtained.

245. Plotting Scales. Ivory. Two specimens, to show fine and accurate dividing. *Aston & Mander.*

No. 1 shows two chains to the inch, represented by 200 divisions to the inch.

No. 2 shows one chain to the inch, represented by 100 divisions to the inch.

247. Longitudinal Measure, according to natural principles. *Hans Baumgartner, Basle.*

250. Half Metre, maple, with points.
Geneva Association for Constructing Scientific Instruments.

251. Brass Metre. (Model of the Grand Duchy of Baden.)
Geneva Association for Constructing Scientific Instruments.

252. Double Steel Metre, with points. (German Model.)
Geneva Association for Constructing Scientific Instruments.

253. Brass Standard Metre. (Swiss Model.)
Geneva Association for Constructing Scientific Instruments.

The Geneva Association for Constructing Scientific Instruments possesses in its laboratories a machine for the division of straight lines, to the construction of which it has endeavoured to apply all the improvements of modern science. Its efforts have been crowned with success, and now the increasing reputation of this machine, which may be considered as the most complete at present existing, has gained for the Geneva Association orders for metrical standards from several European Governments.

The machine is worked automatically, that is, all the process of dividing is done mechanically. Thus it avoids, apart from the inaccuracy consequent on the temperature of the operator, the errors proceeding from the inattention or fatigue of the latter. Mechanical action has, moreover, the advantage of being more regular, seeing that the motive power is always equal.

An ingenious contrivance enables the correcting, during the division of errors due to a change of outward temperature, and to effect at any temperature an exact division at 0°. By the same means, a division of any length may be made, however immeasurable may be ratio of the thread of the screw of the machine to the length of the division required.

The curve of the screw has been thoroughly studied and corrected, so as to guarantee accuracy to the $\frac{1}{100}$ of a millimetre.

This machine for dividing straight lines has been used to effect the normal division of the large machine for dividing circles which stands by its side on the same bed of concrete. This application has been the means of exactly ascertaining the coefficient of dilatation of the machine for dividing straight lines. The maximum of error found in the division of the normal circle was less than a second. It is impossible to expect greater accuracy when it is remembered that the arc of a second on the circumference of the divided circle represents about $\frac{1}{400}$ of the millimetre.

259. Standard Metre, with rack action to be used as a machine for dividing other metres.

Geneva Association for Constructing Scientific Instruments.

This instrument may be used both as a comparative indicator, and as a machine for dividing fractions of the metre, for the use of comptrollers of weights and measures. A small marker slides at will, by means of a rack, along the meter. A very simple lock action enables the millimetric displacements of the indicator to be registered without any other divisional check.

260. A 6-foot Measuring Rod, for uneven ground, for engineering and scientific purposes. Designed by Edward Crossley, F.R.A.S., and made by Messrs. T. Cooke & Sons.

Edward Crossley, F.R.A.S., Halifax.

The apparatus consists of a wooden rod 6 ft. in length, with metal terminations containing spherical cups fitting on to spherical heads upon tripod stands. Three tripod stands are required. Each terminates in a flat ring upon which the base of the short pillar carrying the spherical head is adjustable, and to which it can be clamped. The rod is supported by two tripod stands, while the third is set forward to receive the rod in its next position. The inclination of the rod is read off to half-a-minute in each position by means of a level and arc attached to the centre of the rod. The true horizontal distance is then obtained by applying a tabulated correction for each inclination of the rod.

This instrument will give an accuracy of 1 in 10,000 over any sort of ground, even with a gradient of one in four.

266. Ivory Pocket Measures. *T. Hawksley.*

269. Foot-scale-plate. A rectangular brass-plate containing twenty different foot-scales, made in 1769 by Adam Steitz in Amsterdam. It is a copy from the original deposited in the Town Hall of Amsterdam. *Professor Buys-Ballot, Utrecht.*

275. Meter-measures, constructed of mica. (*See* Nos. 60, 879, 2591, &c.) *Max. Raphael, Breslau.*

These measures have the advantage of being transparent, and may serve for copying geometrical drawings. Owing to their remaining unaffected by the ordinary changes of temperature they may also be used as *standard* measures.

289. Meter Scale with double divisions, for 0° and 20° C., by Breithaupt and Son, in Cassel.

Mathematical and Physical Institute, Marburg (Prof. Dr. Melde).

295. Standard Double Meter on steel, in a case.

F. W. Breithaupt, Cassel.

The normal double meter is a terminal surface measure, as well as a mortise-gauge, with divisions throughout in centimeters, and on both the end decimeters in millimeters. This double meter is graduated on the precision

longitudinal dividing machine, constructed by George Breithaupt in the year 1850, for the temperature of 0° Celsius, as far as 0·01 mm. precision.

Such normal double meters have been made in large numbers on steel, as well as simple normal meters on brass, for the Imperial Commission of Normal Weights and Measures.

With this longitudinal dividing machine a length of one meter may be marked *uninterruptedly* even to the smallest subdivisions.

296. Standard Scales in Rock Crystal, viz.:

a. Scale of 10 cm. cut along the axis of the crystal.
b. Scale of 15 cm. cut in the same manner.
c. Scale of 20 cm. cut " "

The scales are divided into millimeters; the first and the last millimeter are divided into ten parts. The graduation has been carried out by Mr. Brauer in St. Petersburg.

Hermann Stern, Oberstein, Principality of Birkenfeld.

299. Meter in Steel, mortice gauge divided into millimeters. *L. Steger, Kiel.*

301. Apparatus for comparing Standard Measures of Length, by Stollenreuther.

University of Munich (Prof. von Tolly).

302. Meter in the form of a ruler with all sub-divisions.

Städtische Schule at Halle (Mr. Meyer).

303. Schönemann's Measuring Wedge, with 1/100 mm. readings. *Gewerbe Schule at Halle (Director, Kohlmann).*

304. Schönemann's Measuring Wedge, with 1/1000 mm. readings. *Kleemann, Mechanical Engineer, Halle.*

306. Meter-scale in Brass.

Prof. Baron von Feilitzsch, Greifswald.

Apparatus, together with No. 3442 and No. 443, executed at the workshops of Messrs. F. W. Breithaupt and Son in Cassel (Province Hesse), and are distinguished by their great accuracy.

The normal meter is divided, on silver-plated brass, into centimeters, and at both ends into millimeters.

309. Original Meter Scale of iron. One of the forty specimens which were delivered to the members of the Meter-Commission in the year vii. of the French Republic; formerly in the possession of Tralles. *Prof. Dr. Dove, Berlin.*

Original Meter Scale by Tralles (of iron).—One of the 40 standards which were delivered to the Commissioners.

Iron Meter à touts.—This meter, which was presented to Hapler by Tralles, was one of the three which the latter had made at the same time, by Lenoir, with the 15 which were distributed among the members of the Commission.

After the completion of the new measurement of degrees performed by Delambre and Mechain, the real length of the meter was determined by the Commission, consisting of, Swinden, Tralles, Laplace, Legendre, Cizcar, Mechain, and Delambre, in their report of the 6th Florèal year 7, to be 443·295936, and the distance of the Pole, by assuming an oblation of $\frac{1}{334}$,

from the equator having been calculated to be 5130 ys toises, it was legally accepted as "*metre orai et definitif*" at 443·296.

"Cette unité nommée mêtre qui est le dixmillionème partie du quart du méridian revient selon les anciennes mesures à 3 pieds 11·296 lignes, en employant la toise du Peron à 13 degrés du thermomètre à mercure divisé en 80 parties."

312. Standard Meter on brass in mahogany case.
Ed. Sprenger, Berlin.

313. Standard Meter on Steel. *Ed. Sprenger, Berlin.*

314. Standard Meter on Wood. *Ed. Sprenger, Berlin.*

315. Standard Tape Measure, 20 meters.
Ed. Sprenger, Berlin.

315a. Standard Stirling Ell, believed to be a copy of the standard Scottish ell adjusted at Edinburgh, 26th of February 1755. *The Burgh of Stirling.*

B. Telemeters.

226. Telemeter. For measuring the distance of inaccessible objects. *Patrick Adie.*

This instrument, the first of its name, was patented by Mr. Adie in 1863. It consists of two powerful telescopes at the ends of a fixed base; the united rays, by total reflection, give simultaneous observation in the eye-piece.

234. Telemeter, for determining distant inaccessible points by one observation. Manufactured by Adie & Son, Pall Mall.
Professor Pigot.

242. Nolan's Range Finder.

1. Two-angle measures. Right and left.
2. Two Y supports.
3. Two tripods.
4. Two tripod buckets.
5. Two leather boxes with straps to contain items 1 and 2.
6. A 50 yards measuring tape.
7. A metal calculating roller.
8. Two magnifying glasses.
9. A leather case with strap to contain items 6, 7, 8.
10. A leather numnah which fits under the saddle of item 1, and on which the two boxes, item 5, are strapped.

War Office.

243. Two Instruments for Measuring Distances. Executed by Dr. Meyerstein.
Professor W. Klinkerfues, Göttingen.

262. Telemeter with prism by Col. Gautier for the rapid measurement of distance. *M. Tavernier Gravet, Paris.*

263. Pocket Telemeter. By M. Gautier.
M. Tavernier Gravet, Paris.

264. Telemeters. *Fortin, Hermann Bros., Paris.*

285. Collection of War Telemeters. These instruments, which are based on the speed of transmission of sound, are intended for measuring distances in the field.
Le Boulengê, Liége.

307. Instrument for Measuring Distances, according to the systems of Kleinschmidt and Breithaupt.
Royal Museum at Cassel (Dr. Pinder, Director).

The instrument for measuring distances was executed completely in brass by J. C. Breithaupt, during the second half of the 18th century. It consists of a rail of 0·978 m. in length, serving as measuring-base, on both ends of which is attached a movable telescope for sighting the object the distance of which is to be determined. By the known length of the base, and the indicated angles which the adjusted telescopes form with the fundamental line, the distance looked for is ascertained by trigonometrical calculation.

C. Gauges and Callipers.

236. Sliding Calliper Gauge, with tangent screw and vernier for reading $\frac{1}{1000}$th of an inch inside and outside measurement. *Elliott Brothers.*

237. Decimal Gauge, German silver, with screw and ratchet motion for measuring to $\frac{1}{1000}$th of an inch. *Elliott Brothers.*

246. Aerial Spider Line Micrometer of great delicacy, measuring an object to the 100,000th of an inch.
Dr. Royston-Pigott, F.R.S.

The image of sets of spider lines of a recording micrometer placed beneath the stage, is formed by a half inch objective, five inches from the spider lines. This image is in fact a miniature diminished exactly seven times. The micrometer reads to the 1–20,000th of an inch, $\frac{1}{20000}''$; consequently the image is measured seven times more minutely. This would be the 1–140,000th, or $\frac{1}{140000}$th of an inch (English). On the whole, therefore, the instrument may be said to measure to the 1–100,000th, *i.e.*, $\frac{1}{100000}$th of an inch.

These aerial spider lines are made to move about the object to be measured at the will of the observer, and come into the focus of the microscope by regulating the plane of the aerial spider lines.

256. Callipers, for clock and watch making.
Geneva Association for Constructing Scientific Instruments.

Much used in clock and watch making for measuring thicknesses. This instrument gauges to the fraction of $\frac{1}{80}$th of a line, or $\frac{4}{100}$th of a millimetre.

The divisions traced on the steel arc are not equal, but are calculated to measure equal increments of the interval between the two nibs. They increase therefore with the chords.

257. Curious Steel Callipers for very accurate measurement, by Paull of Geneva, 1777. *Royal Society.*

267. Apparatus for **measuring** the exterior **diameter** of the **Gun Barrel** and the interior diameter of the rings to be spanned on the same ; constructed by G. Brauer.

Arsenal of St. Petersburg.

The apparatus consists of a rod (bar), which is placed right across the cannon, and suspended, on which two arms can be moved; the one arm is brought into contact on one side with the surface of the cannon, whereupon the other arm with its contact lever is brought into connexion with the surface of the cannon on the other side, in such a manner that this contact lever at its upward and downward motion through the vertical screw at the greatest diameter indicates zero. In order to exactly determine the diameter, the divided movable scale is pushed, after taking off the apparatus from the barrel of the cannon, between the two arms, and slided so until the contact lever again indicates zero. The same scale serves also for measuring the interior diameter of the rings. The apparatus has been constructed and made by G. Brauer at St. Petersburg.

267a. Photograph of an Apparatus for **measuring** the eccentricity of the chamber and the curve of the **bore** of **cannons.**

G. Brauer, St. Petersburg.

The apparatus consists of two parts :—

1. A body, which is squeezed into the mouth of the cannon by means of an endless screw. In this screw a telescope is fixed which can be turned about its own axis, and is provided with a Filar micrometer and a position circle.

2. A piece, which can be slided along the barrel, being turnable about the axis of the bore, and in whose centre is a glass plate with engraved cross. This cross is viewed through the telescope before mentioned, and the determination of the position of the cross on the Filar micrometer indicates the elements for determining the curve of the bore and the eccentricity of the chamber.

The apparatus was constructed by the exhibitor for the Russian Marine Artillery Department.

267b. Instrument for **Measuring** the **Bore of Cannons** (Etoile Mobile). *G. Brauer, St. Petersburg.*

This instrument consists of a ring, in which slide two parallel rods lengthways side by side, and of which the one carries the scale, the other the vernier to it. The sliding rods are driven asunder by means of springs, so that their exterior steel ends touch the side of the bore to be measured. As this contact must not take place during adjustment, the sliding rods are pushed together by a bolt. A screw perpendicular under the sliding rods is intended for adjusting them according to the greatest diameter, which has to be done afresh at each measurement. If the chamber of a breech-loading gun is to be measured with the apparatus a set of two rings has to be added, of which the one in front carries a telescope for viewing the scale. The two exterior rings are joined to each other by four bars, and these bars have a movement in the centre ring, which during the operation of measuring is squeezed into the back part of the cannon bore by means of four screws, and the whole apparatus is then moved as required.

267c. Apparatus constructed for **measuring** the exterior **diameter** of small **cylinders** with an accuracy of 0·001 inches.
G. Brauer, St. Petersburg.

This apparatus, which was employed at the experiments as to the elasticity of gun-metals, steel, cast-iron, &c., in Russia, is provided with an immoveable pillar and a contact-lever, which can be displaced by means of a screw-movement. The cylinder to be measured is placed between the two, and the screw turned until the lever points to zero, and then the reading is effected by the vernier of the longitudinal scale.

267d. Apparatus for **Measuring** the **Length** of the **Impressions** made by the **Rodman Scale.**
Technological Institute at St. Petersburg.

The copper plate, on which is the impression to be measured, is placed on the sledge of the apparatus, and then one end of the impression after the other brought under the thread cross of the microscope by means of the screw of the sledge, whereupon the reading can be made at the top of the screw. By means of an ocular micrometer also shorter longitudinal dimensions can be measured.

The apparatus belongs to the Technological Institute at St. Petersburg.

271. Calliper, with **Dial,** of the inch English measure, divided into eighths of an inch. *M. Isvard fils.*

272. Calliper, with **Dial** of two centimetres, divided into tenths of a millimetre. *M. Isvard fils.*

283. Cylindrical Gauges differing in diameter by one ten thousandth of an inch. Other gauges and specimens of surfaces.
Royal School of Mines.

284. Universal Calliper, with slide and reverse action.
Geneva Association for Constructing Scientific Instruments.

Instrument of measurement, for ascertaining equally the thickness, the inner diameter of tubes, and their height. The latter by reversing the moveable nozzle.

286. Apparatus for measuring accurately the **Diameter** of **Wires,** for testing whether pivots and other turned objects are perfectly circular in form, and for the determination of the error when they are not truly circular.
Landsberg and Wolpers, Hanover.

287. Apparatus for measuring the Thickness of thin metal plates, sheets of paper, &c.
Landsberg and Wolpers, Hanover.

288. Calliper-Compasses for larger arcs.
Landsberg and Wolpers, Hanover.

288a. Photographs, showing two kinds of machines for measuring with great precision the alterations in shape produced in metals by tension and compression. *Dumoulin Froment, Paris.*

The curve scale is intended for engineers, steam boiler makers, surveyors, architects, and others, for copying maps, plans, &c.

It will be of great advantage in the projection of railway lines, the curve scale requiring only to be adjusted to the situation in order to ascertain how the line can be most favourably traced, and expensive cuttings avoided. In regard to such surveys, as well as in the control or examination of railway lines already traced and sketched (for which purposes either the bow, cut out according to certain radii, or compasses, are used at present), the employment of the curve scale will save the tedious trouble of experimenting, since the correct curve can be immediately determined and read by means of this instrument.

Boiler manufactures, also, and almost all technical pursuits, will find the curve scale very useful for determining the radius of part of an arc of a circle, of which three points are given, as, for instance, in arched steam boiler bottoms.

In fact, in all cases where part of an arc of a circle, or three points of the same, is given, the radius can be read direct, and without loss of time, in a manner hitherto unknown.

If it be desired to take the radius of a given curve by means of the scale, the middle bar of the same is placed on the curve line, and the scale is then moved so far upwards or downwards until the curve line meets in three commensurably described points of the scale. The number indicated gives the radius of the curve in centimeters, if the curve is drawn in its natural size.

If, however, the drawing of which the radius of the curve is to be determined is sketched, as is usually the case, in a reduced scale, the radius indicated must be multiplied with the proportional number of the reduced scale.

For example, if the drawing should be sketched in $\frac{1}{2500}$ scale of the natural size, and the curve radius on the curve scale is indicated with 52·5 cm., the actual radius of the curve will be $52 \cdot 5 \times 2{,}500 = 131{,}250$ cm., or 1,312·5 meters; or, should the drawing be sketched in $\frac{1}{500}$ scale, and the curve scale indicates 43 cm., the radius of the curve will be $43 \times 500 = 21{,}500$ cm., or 215 meters.

The curve scale can likewise be used as a reduction scale of every other measure which is to be calculated in meter measure, as the radius in meters can always be read directly, no matter in what scale the drawing is made.

This is a great saving of labour, which is very much facilitated if, as often is the case, old maps and drawings are to be made use of.

In using the curve scale it will sometimes happen that the curve to be ascertained does not exactly meet the line drawn on the scale, but will fall between two lines. In this case the smaller division can, as the radii are marked progressively by 0·5 cm., be easily estimated with the naked eye after a little practice.

For example, the curve of the radius of 1,110 meters, at a proportionate scale of $\frac{1}{2500}$, lies between 88·5 and 89·0 of the curve scale, and amounts to nearly 88·9.

As, however, in most cases, round numbers, without fractions, are chosen for the radii, the radius can always be determined with the greatest accuracy.

291. Calliper Apparatus, for accurately determining diameters and lengths up to 150 mm.

A. Meissner (H. Müller and F. Reinecke), Berlin.

The calliper apparatus is to be employed for the exact determination of diameters and lengths, as far as 150 millimeters; the $\frac{4}{1000}$ part of a millimeter by estimation, and $\frac{1}{25}$ millimeter by direct reading by means of a microscope.

293. Collection of Timber Callipers for the use of foresters. *C. Staudinger and Co.* (*F. W. von Gehren*), *Giessen.*

A collection of tree-clamps ("Baumklieppen"), mostly in use for the purpose of comparison with those of Staudinger's construction, by many authorities recognised as the best. A list of the names is added to the collection.

298. Calliper Compasses, with plane contact lever.
Physical Institute of the University of Kiel (*Prof. Dr. G. Karsten*).

This apparatus, which is in the possession of the Physical Science Institute of the University of Kiel, was constructed in 1832 by Repsold, and made use of by Schumacher for comparing the platinum kilogramme of the archives with the Danish.

(*See* Schum. Astronom. Jahrbuch, 1836, p. 243.)

A description of the instrument will be found in G. Karsten, "Vom Maasse und vom Messen," vol. I. of the "Encyclopædia der Physik," p. 506 and following.

308. Apparatus for **measuring** the **Thickness** of **Thin Plates.** *R. Fuess, Berlin.*

The instrument serves for demonstrating the bending of strong masses of metal by very little pressure and the expansion by heat; also for determining the expansion coefficients of bars of 10 cm. length.

D. Cathetometers.

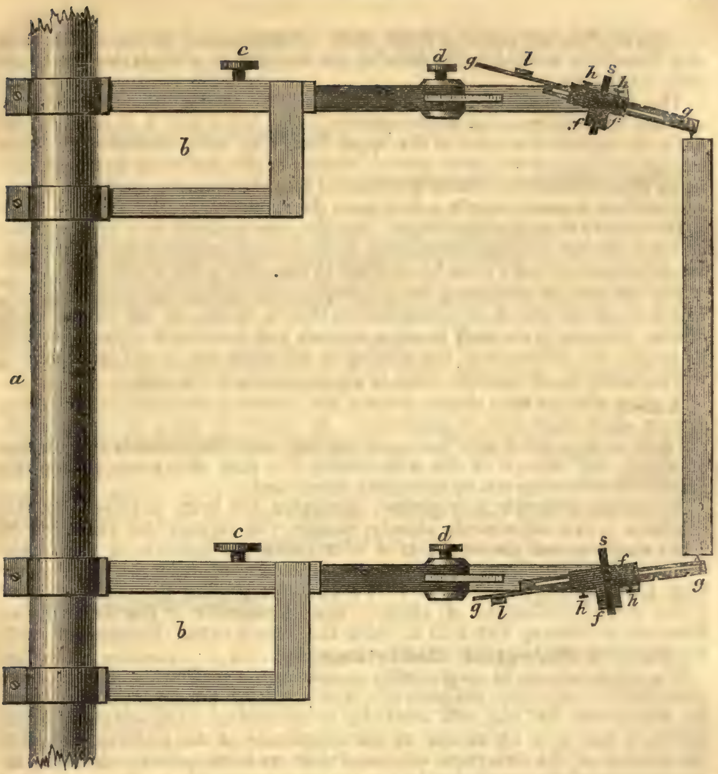
241. Differential Cathetometer, an apparatus designed for measuring variations in the length of solid bodies, particularly of rods and wires. *Dr. Heinrich Streintz, University of Gratz.*

The principle on which this apparatus is based is, reading by reflection from two mirrors. Two levers, having small mirrors *s* attached to them perpendicular to their axis, are turned by the flat ends of the bar to be measured as indicated in the drawing. If a telescope and a scale are placed, at some distance, in such a position that the image of the scale reflected by the mirror is visible through the telescope, each variation in the position of the point at the end of the lever will be magnified to a degree indicated by the quotient, the numerator of which represents the double distance of the mirror from the scale, and the denominator that of the point from the axis of rotation.

As the latter distance can be diminished to one centimeter in the apparatus, and as, moreover, the telescope with the scale can be placed at any distance within which distinct images will be seen, say five metres, a shifting of the reflected image by one millimeter will be equal to displacement of the end-surface of the bar to be measured by 0·001 millimeter. As, however, the tenths of the millimeter can be still pretty accurately determined, the reading will be correct as far as the 10,000th part.

There is no doubt that the correctness of the reading with this apparatus can be carried still further, if mirrors of superior quality and powerful telescopes are employed.

In measuring the variations in the length of wire a flat surface must be given to that part on which the wire is to be suspended, as well as to the part on which the weights are placed, and to which as flat surfaces the levers are to be applied.



The arrangement of the apparatus is as follows :—

In a solid brass pedestal, which rests on three adjusting screws, there is cemented a strong glass tube *a*, $1\frac{1}{4}$ meter long, to which two brass bars *b* are affixed. Each of these brass bars consists of two parts, of which the one moves or slides in the other in such a manner that it can be either lengthened or shortened. The screw *c* serves for fixing the chosen length. By means of the joint *d* a horizontal rotatory or veering movement of the fore-part of the bar can be effected. Close to its free end there is on each side a steel point—the two forming together an axis—which is held by a bow *ff* carrying two pans, in such a manner that the bow can be easily but surely turned round this axis.

The lever *gg* which must be firmly connected with the bow, has longitudinally a slit, or slide, with two sliding pegs placed in a level position with the axis and fastened to the bow, along which the lever can be moved, so that at whatever distance from the axis the extreme end of the lever may be fixed the lever must always turn with the bow around the axis.

In order not to be obliged to take the measurement of the length of the lever afresh at each experiment, the lever is provided at its upper surface with conical-shaped cavities in which the screws *hh* catch. These conical-shaped cavities would be, properly speaking, visible only in a drawing of a

vertical section, but not in a front view, as represented in the sketch, but they have been marked in the drawing for the purpose of rendering the latter more intelligible.

The measurement of the length of the lever at the different cavities is accomplished by means of a spherometer. The lower bar *b* is arranged in quite an analogous manner as the upper bar, with this difference, that this one presses against the lower extreme surface of the staff to be measured, *i.e.*, in an upward direction, whilst the one just described presses upon the upper end surface, consequently in a downward direction.

In order to meet the requirement that the levers should only press against or touch the end surfaces but slightly, in the manner indicated in the drawing, small balancing blocks *l* can be attached at any part to the levers.

For the purpose of reading two telescopes with vertical scales are required, which must be placed in juxtaposition, that is to say, by the side of each other. Presuming the staff to move upwards and downwards without varying its length, the difference in the reading in the upper and in the lower mirror will naturally be of the same value in every position of the staff.

A glass tube has been chosen to serve as a column *a*, because glass possesses a very small coefficient of expansion. Moreover, in using the instrument, the tube must be filled with water and two thermometers placed in it, by means of which any change in the temperature that may take place during the process of measuring can be accurately determined.

A similar, although less perfect, apparatus has been employed by the exhibitor in two experiments already, namely, "as regards the variations in "the elasticity and the length of a wire under the influence of a galvanic "current." *See* Transactions of the Academy of Sciences at Vienna, Vol. LXVII., Part II., April 1873; and "respecting the moderation of "the torsion oscillations of wires." *See* Transaction of the Academy of Sciences at Vienna, Vol. LXIX., Part II., March 1874. Extracts of both treatises have also been published by Pogg. Ann.

The apparatus can be employed in measuring the coefficients of expansion, coefficients of elasticity, the after effects of elasticity, the expansion produced by magnetism, &c., and will secure in every case an accuracy not hitherto achieved, not only by reason of the correctness of the readings, but also on account of the correction of temperature rendered possible through the employment of the glass column.

The measurement is likewise very easy of accomplishment, since a manipulation such as is the case with ordinary cathetometers is not required, as the variations taking place in the wire can be perceived through the telescope directly magnified and projected on the scale.

In most cases it will only be necessary in making such experiments to know exactly the absolute length of the body to be measured in equal per cents, as well as the elongation, for measuring which a good scale, or a very simple cathetometer, is all that will be required.

241a. Original Cathetometer by Dulong.

Polytechnic School, Paris.

241b. Cathetometer, with two Levelling Micrometer Telescopes.

Physical Science Cabinet of the Imperial Academy of Sciences at St. Petersburg.

241c. Drawing of a small Cathetometer, used by Prof. Mendeleeff in his investigations on the tension of gases.

In order to eliminate a source of many errors the eye-piece is fixed in the telescope, and the whole cathetometer has to be put at the required distance from the object to be observed.

The telescope is provided with a micrometer screw.

258. Great Cathetometer, for reading differential levels more than a metre apart.

Geneva Association for Constructing Scientific Instruments.

This instrument is composed of a tripod supporting a central rod, which bears on its upper part the brass column, that is, the prismatic piece, along which the telescope moves in a parallel line. The dimensions of the column are great, so as to avoid all flexure. The division on the silver plate is in millimeters, and the vernier of the sliding carriage registers to the 50th of a millimeter. This instrument has two levels; the one placed between the rings that support the telescope, the other placed perpendicularly to the first upon the table situated at the base of the column.

The universities of Berlin, Rome, Dorpat, Neuchatel, &c. have this instrument.

273. Cathetometer, by Casella. The telescope moves on a girder-shaped brass bar, to which the scale is attached, and is furnished with a micrometer eye-piece, by means of which readings can be taken without moving the telescope. The instrument is supported by a massive iron frame-work.

Prof. A. W. Rücker, Leeds.

292. Cathetometer. *C. Bamberg, Berlin.*

The principal division of the instrument is executed on silver from centimeter to centimeter. A division into single millimeters has been made on a lid connected with the principal slider, whose surface of division is on a level with that of the centimeter graduation. The millimeter lid moves with the principal slider, which carries the means for reading and adjustment (microscope and telescope). The reading of the meter-division is effected (as far as 0·001 mm.) by means of the ocular screw micrometer of the microscope. The micrometrical displacement of the principal slider, which balances perfectly around the longitudinal axis of the scale prism, takes place by a peculiar contrivance, which avoids all one-sided pressure. The slider with the cramp operation is balanced by a counter-weight suspended from the ceiling or a trestle, so that its ascending and descending motion is effected with great facility.

294. Photograph of a Cathetometer, made by Staudinger and Co. *C. Staudinger and Co. (F. W. von Gehren), Giessen.*

The peculiarities of the construction may be learned from the photographs. The instrument has a useful division of one meter length; the prism with the counter-weight turns completely around the long vertical axis; the prism is provided with adjusting appliances which render the direction of the same to every side possible; reversional telescope and water-level.

305. Cathetometer.

Prof. Baron von Feilitzsch, Greifswald.

The cathetometer consists of a central axis, and a prism turning round the same. For placing the central axis in a vertical position a cylindrical water-level, indicating 10 seconds, is employed. A silver scale of one meter

in length, and divided throughout into millimeters, is inlaid into the prism. Sliding along the same is a telescope, likewise fitted with a cylindrical water-level, the supporter of which is provided with a nonius indicating $\frac{1}{20}$ mm. Added to the same is—

Water-level, for regulating the direction of the prism.

310. Cathetometer, so arranged as to be used as horizontal measure; can be unscrewed. *Prof. Dr. Dove, Berlin.*

311. Cathetometer, by Breithaupt and Son, in Cassel, with riding level. *Polytechnic School in Cassel (Dr. E. Gerland).*

1. The following improvements, contributing partly to more minute indications of the apparatus, partly allowing the correction of the several parts the one to the other, have been added to the well-known construction of cathetometers.

The firmly placed central axis, around which the long case with prism turns, can be placed vertically by a special cylindrical water-level, indicating 10 minutes; the latter is therefore fastened to that case independently of other parts, in order that the vertical position of the axis required at very fine measurements can be easily observed; the more so, as all other examinations are based on the correct adjustment of this water-level. The vertical position of the axis is effected in the same manner as with an ordinary levelling instrument, and any deviations of the water-level are corrected half on the correction screw of the same, and half by the regulating screws of the tripod.

The prism, the inlaid silver scale of which, of 1 meter in length, is throughout divided into millimeters, and fitted with a vernier for $\frac{1}{20}$ mm., can be placed in a perpendicular and a horizontal position towards the axis of revolution. For this purpose a specially constructed attaching or adjusting water-level, which is fastened to a right angle, and can be turned, is placed on the face, and the edges of the prism, and thereby the latter, which has at the sides and behind regulating screws for that purpose, is corrected as required; at this correction it is necessary to pay particular attention, by means of water-level attached to it, to the exact perpendicular position of the axis of revolution.

After the telescope water-level has been previously examined by reversion and adjusted, the rectangular position of the telescope towards the prism is effected by screws, which allow a slight raising or lowering of the telescope supporter. If this is done, the bubble of the telescope water-level will remain unchangeably in the centre at the turning of the whole instrument around its central axis, as well as at the upward and downward motion of the shifter.

A very severe proof consists in sighting with the telescope a distant object, the telescope being reversed in its sockets, and the apparatus turned round 180°, at which manipulation the former object must be intersected again by the ocular cross what must always be the case with an exactly constructed and well rectified instrument.

The unalterable cross in the ocular is cut in glass, in order to prevent hygroscopical and other interruptions. For the purpose of obtaining the rectangular position of the telescope, the supporter may also be placed with one end between points, while an elevation screw is fixed to the other. The essential point for effecting the before-mentioned correction by employing the attaching or adjusting water-level consists simply in adjusting the water-level axis exactly to the leaning face by means of the correction arrangement marked *a* in the drawing. The proof is effected by reversing the angle

vertically, the water-level turning thereby between its points. If after the proper attachment the bubble deviates from the centre, half of this deviation will be corrected by the regulating screws of the tripod, and the other by the said correction arrangement *a*. It is, however, to be mentioned that *previous* to the above proof the parallel position of the water-level axis towards its points of attachment is to be examined, which can effected by reversing between its two points, and thereby a deviation of the bubble, if there be any, will be removed half by the adjusting screw *b*, and the other half by the arrangement *a*. Finally, there remains the examination and correction of the water-level sideways to be made, which is done in the usual manner by the screw *c*. This attaching or adjusting water-level may also be recommended for other purposes, for instance, in mounting of machines, &c.

Regarding the peculiar construction of the aforesaid adjusting water-level, the suspension between two points, in general, it may be remarked that the same has been derived from the compensation-level constructed by F. W. Breithaupt and Son some years ago (vide Dingler's Polytechn. Journal, vol. CLIV. p. 401). In what manner this principle has been adopted by other mechanical workshops, and represented partly as an invention of their own, has been proved by an article in this Repertorium, vol. IX., p. 127, by the addition of an arrangement or simplification totally at variance with the construction.

E. Dividing Engines.

248. Instrument for **dividing Mathematical Scales** or **Rules.**

Lent from the Patent Office Museum by the Commissioners of Patents.

This instrument is to be used for dividing scales according to the French, Swiss, or English measures of length, and is provided with a vernier for obtaining the smaller divisions of the scale. It can also be adapted for producing diagonal scales.

265. Machine for **dividing right lines,** by Nicholas Fortin.

MM. Fortin Hermann Bros., Paris.

This machine is that constructed by the celebrated inventor in 1787, and used in the works connected with the adoption of the metrical system.

The pitch of the screw is exactly one millimetre. (Fortin's machine for dividing circles, as well as this machine, was presented to the Conservatoire des Arts et Métiers by MM. Fortin Hermann Bros., in 1876.)

297. Micrometer Dividing Machine.

Voigt and Hochgesang (Gust. Voigt), Göttingen.

The screw of the dividing machine has a rising gradient of $\frac{1}{4}$ mm. to 0·25 mm. The top of the same is divided into 200 parts; each part, therefore, corresponds to $\frac{1}{800}$ millimeters. The nonius supplies a reading of $\frac{1}{10}$ of this value. By a spring fixed in the inside of the prism the dead movement of the screw will be completely removed.

The tracing appliance is constructed in the simplest manner possible. The tracing point—a diamond—is lifted by a mechanical contrivance, and let down again.

The sledge allows of drawing a line of 30 millimeters in length.

For constructing *ocular micrometers* there is an arrangement making three linear lengths in a mechanical manner.

The sledge which carries the tracing work moves without greasing between six finely polished carnelian plates; by this arrangement any errors, which might be caused by clotted grease, will be rendered absolutely impossible.

297a. Micrometer Gauge and Screw, unfinished; divisions adjusted to show $\frac{1}{10000}$th of an inch.

Maudslay Sons and Field.

297b. Micrometer (Screw) Gauging Machine, by the late Mr. Henry Maudslay, divided on the head of micrometer screw to show $\frac{1}{10000}$th of an inch.

Maudslay Sons and Field, Engineers, Lambeth.

F. Tide Registers.

255. A Registering Water-mark, of new construction, which records the curve of the water-level and its mean height.

Lieutenant-General Baeyer, President of the Geodetic Institute at Berlin.

678. Complete Magneto-electric Water-level Indicator. *Siemens and Halske, Telegraph Works, Berlin.*

279. Three Gauges, in enamel cast iron, for registering the height of a river or lake. *De Dietrich and Co., Niederbronn.*

The first of these on the Niederbronn pattern is in black and white and graduated to centimetres, the second on the Nancy pattern is graduated in black and white for every two centimetres, and the third on the Paris pattern is in blue and white graduated to five centimetres.

These water-mark posts are fixed by means of iron clamps to piers, vertical embankments, &c., and serves for the observation of the stand of the water in rivers, canals, lakes, and ponds.

Placed properly distanced from one another into the chief water-courses and its tributaries, it permits to observe the rise of the water, and consequently the giving of timely warning, by telegraph or otherwise, to the inhabitants of the districts concerned.

280. Recording Tide Gauge, with self-acting calculation of the mean height of the water (system, F. H. Reitz, Hamburg); executed by Dennert and Pape, in Altona.

Royal Prussian Geodetic Institute, Berlin.

The tide-measuring system exhibited by the Royal Prussian Geodetic Institution of the European measurement of a degree, at the instance of its president, General Baeyer, constructed by Dennert and Pape of Altona, with clock by T. Knoblich, of Hamburg, has a graphic apparatus for registering the tide-curve and an arrangement by which the mean water-level is indicated automatically. The registration of the water-level is effected by means of diamond points upon a cylinder placed horizontally for the accurate division of the arc; for the indication of the water-level a peculiar dividing machine accompanies the flood-measurer.

The mean water-level is indicated by means of two agate rollers with divisions, which slide upon a horizontal glass disc turned by the clock of the

tide-measurer, moved to and fro by the rising and falling water, and by the rotation of the glass disc, and may be read off at any desired intervals of time.

The calculation otherwise necessary of the mean water-level (the true level of the sea) from the indications of the registering apparatus is saved by the above-mentioned mechanical arrangement, and effected automatically with very great accuracy by the tide-measurer.

281. Self-recording Tide-gauge, improved.
H. C. Ahrbecker.

In this model the whole of the paper can always be seen, and requires renewal only once a month. The clock goes for 32 days.

282. "Maréegraphe," or tide-gauge. *Van Rysselberghe.*

G. Miscellaneous Length-measuring Instruments.

238. Measuring Wheel for determining distance by registering the number of revolutions ; the upper index pointing out every single and the lower every 100 revolutions.
Elliott Brothers.

238a. Odometer or Way Measurer in gilt metal case elaborately chased, an early example probably made in the second half of the 16th century. *Alexander Nesbitt.*

In Beckmann's History of Inventions is a description of two instruments resembling this, which belonged to the Emperor Rudolph II. (1576–1612).

240. Improved Measuring Wheel or Mile Meter.
Elliott Brothers.

270. Holt's Diagrammeter. This instrument is specially made for measuring the ordinates of indicator-diagrams 5″ long, and is used much after the manner of a parallel rule, the registering nut on the screw being first placed at zero ; when it is required to register a measurement the key for break is depressed, and when all the measurements have been taken the distance the nut has travelled gives the mean ordinate. *Henry P. Holt, C.E.*

274. Spherometer (by Salleron), to read to ·001 mm.
The Council of the Yorkshire College of Science, Leeds.

276. The Wealemefna.—A pendant for the watch-chain.
The Morris Patents Engineering Works, Birmingham.

To measure, it is merely necessary to advance the Wealemefna over the object, when the large hand will register the inches and fractions of an inch, and the small one the feet. The instrument registers to 25 feet.

277. Measuring Instrument, for the use of architects, surveyors, builders, contractors, timber merchants, &c. &c., and for general measuring purposes, in place of the rule or tape.
The Morris Patents Engineering Works, Birmingham.

To use the instrument it is merely necessary to advance it along the object to be measured, when the large hand will register the inches and fractions of an inch on the outer dial, the smaller hand on the inner dial, the feet and the smallest hand on the recessed dial, the tens of feet travelled over. The instrument registers to 100 feet. Price, electro-silver, in leather case, 16*s.* 6*d.*

277a. Pedometer, of the latest and most approved form.
J. and W. E. Archbutt, Westminster.

This instrument has pendulum action, and is worn suspended in the waistcoat pocket; it is provided with a regulator whereby it can be set to most accurately record distances walked.

277b. Improved form of Pedometer, by Dolland, in which the direct chain action is substituted for the lever made in the early part of the nineteenth century.
J. and W. E. Archbutt, Westminster.

277c. Pedometer or instrument for accurately registering distances walked. This instrument was invented and made by Spencer and Perkins in the latter part of the eighteenth century. *J. and W. E. Archbutt, Westminster.*

278. The Chartometer. E. Russell Morris's patent. (Silver Medal, awarded at Manchester, 1875.)
The Morris Patents Engineering Works, Birmingham.

The only instrument that measures and registers distances on maps, plans, scaled drawings, &c., and that is adapted for various scales. By guiding the small steel wheel along any route on a map, the hand registers the actual distance in miles, yards, &c., according to the dial in use and the scale of the map, which should correspond. To deal with a map of a difficult scale, the glass front is opened by pressing a spring; the dial removed, and another corresponding to the fresh scale slipped into its place. A set of dials adopted to the scales of all the Ordnance maps, and the usual scales of travelling maps, &c., &c., is contained in a recess of the leather case, beneath the instrument.

290. Scale for Measuring Curves. Eschenauer's patent.
Hermann Schäfer, Darmstadt.

1093a. Ellipsometer.

Before the eye-piece of the glass, a double refracting prism is made to turn until a wire, moving perpendicularly to the principal section of the prism, gets to pass through the two intersecting points of the two reflections of the ellipse. An index shows at the moment the position of the prism.

III. MEASUREMENT OF AREA.

316. Amsler's Planimeter, for calculating with perfect accuracy the contents of plans, maps, or other plane surfaces, in square inches and metrical measure. *Elliott Brothers.*

317. Polarplanimeter. *A. Ott and G. Coradi, Kempten.*

By means of the polarplanimeter the superficial contents of any kind of figures drawn on paper, no matter what their outline may be, can be ascertained by mere tracing more exactly and quickly than by any other method.

The inventors of this instrument are respectively J. Amsler, in Schaffhausen, and Ch. Harke, in Vienna. Ott and Coradi's construction is a combination of both, embracing the excellences of each. It differs from Amsler's instrument by the pole (axis) of the instrument not being formed by an inserted point of a needle, but by a steel ball embedded in a metal cylinder, thus giving it a firmer position; and, moreover, by the axis of the roller being lodged in a horizontal frame, and the dividing circle of the roller (cylinder) as well as the indicating wheel being free at the top, thereby affording much easier and more accurate reading than Amsler's instrument. This arrangement has the advantage that for simple calculation the zero point of the drum can be placed exactly on the zero point of the nonius, when the tracing pencil is at the commencement of the figure. The weight can be separated from the instrument, by withdrawing the bolt, and placed in the case by itself. The runner carrying the axis of the polar arm can be moved along the whole length of the quadrangular bar, by which means at every agreeable longitudinal scale a round number can be obtained for the value of the nonius unit (for example, scale 1·500 nonius unit, 2 square meters, or scale 1·1440 nonius unit, 5 square fathoms). The tracing bar is divided into ½ mm., and the runner sliding on the same carries on one side a nonius, on the other an index. For adjustment with the index, the most usual or specially desired longitudinal scales are marked with lines on the bar; by means of the nonius and the divisions on the bar, proportions of measure not previously given can be easily inserted and noted down; in the same manner, in the case of plans which have been drawn on shrivelled paper, the area can be retained in its actual size by a corresponding movement of the runner, and the position of the nonius noted down for a certain amount of shrivelling.

318. Planimeter, divided on a glass plate, in a case.
F. W. Breithaupt, Cassel.

The planimeter consists of a net marked on a glass plate for a certain relation of the meter measure.

319. Wetli's Planimeter.
Physiological Institute of the University of Halle (Prof. Bernstein, Director).

The planimeter is fitted together by placing the six-toothed movement into the centre of the divided disc, whilst the central point of the small glass disc moves at the other end in the screw of the hoop encircling the divided disc. Next, the sledge with the large glass disc is placed on the three-railed track in such a manner that the horizontal glass disc comes underneath the smaller vertical one; the latter is then, by means of the screw which is fixed on the hoop, regulated in such a manner that it is easily carried along by the horizontal disc by friction.

The pointer moving with the same on the same axis on the dividing disc indicates by a pencil, easily observable by watching the instrument, the figure according to its superficial contents in quadratic millimeters. The toothed little wheel contrives a reading of every 1,000 quadratic millimeters of the traced outline of the surface.

IV. MEASUREMENT OF VOLUME.

321. Schmid's New Water Meter. *A. Schmid, Zürich.*

This meter consists of two of Schmid's patent hydraulic motors, coupled at right angles, and enclosed in a water-tight casing. They are set in motion by the force of the fluid they have to measure. At each revolution a volume equal to the contents of four cylinders must pass. The pressure required to keep tight the oscillating surfaces of the cylinders is furnished by the difference of pressure at inlet and outlet, which is thus self-regulating. The meter is also kept in motion by the difference of pressure. The frictional resistance is the same with all pressures of the fluid under measure, and, according to the size of the meter, is represented by a water head of 3 to 16 ft. The different parts of the meter are constructed of materials not liable to chemical influence.

The chief advantages of this meter are:—

1. The velocity of the engine is exactly in proportion to the quantity flowing through the meter.
2. According to the most careful experiments, the error, if any, does not exceed 1 per cent.

321a. Siemens' and Adamson's Patent Water Meter.
Guest and Chrimes, Rotherham.

This meter has a great resemblance to the motive-power machine known as Barker's Mill. The water passes down through a funnel into the measuring drum, and in passing outward through the curvilinear channels of the same causes it to revolve, delivering a certain quantity of water at each revolution of the drum, and this is indicated by worm wheel and gearing, in gallons, feet, or any other measurement required, on a dial plate properly divided and prepared for the purpose.

The meter is exhibited in section, so that the internal arrangements and its action can be seen. This meter has been extensively used for upwards of 20 years.

321b. Half-inch Patent Water Meter, for the water supply for domestic and trade purposes on the constant supply system.
J. Tylor and Sons, London.

322. Measures of Capacity, according to natural principles.
Hans Baumgartner, Basle.

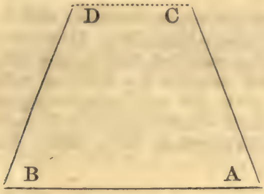
323. Measures of Quantity, according to natural principles.
Hans Baumgartner, Basle.

324. The Standard Pint, popularly known as "The Stirling Jug." *The Burgh of Stirling.*

This measure was entrusted to the town by Act of (the Scottish) Parliament, in the year 1437. Sometime previous to 1745 it had been borrowed by a coppersmith for the purpose of making others, and as he joined the insurgents in "45" it was lost sight of. On his not returning, his effects were sold, all but a few that were thrown into a garret as rubbish; among these, in 1752, the Stirling Jug was found, after some years of patient and unwearied search (by Rev. A. Bryce, of Kirknewton). It is made of brass, and is in the

shape of a hollow truncated cone, weighing 14 lbs. 10 oz. 1 dr. 18 grs. Scottish troy. Diam. of mouth 4.17 English in., of the bottom 5.25 in., and depth 6 in. On the front, near the mouth, is a shield in relief, bearing a lion *rampant,* the Scottish national arms, near the bottom is another, bearing an ape *passant gardant,* supposed to be the arms of the foreign maker.

324a. Russian Standard Measures of Capacity (Vedro, $\frac{1}{2}$ V., $\frac{1}{4}$ V., $\frac{1}{10}$ V., $\frac{1}{100}$ V.). *Siemens and Halske, Berlin.*



These measures, made of bronze, have a conical shape, newly adopted in Russia, for standard and trade measures of capacity. In these measures the inner diameter, A B, of the bottom is equal to an inner side, A C, and double diameter, C D, of the orifice. By very simple contrivance, such trade measures might be verified, approximately, by (linear) measurement of A B, A C, and C D.

325. Set of Standard Measures for Alcohol, conical shaped, in order to diminish the possibility of evaporation of the liquid. *Siemens and Halske, Berlin.*

326. Water-meter, for cold water, for 26 mm. width of tube. *Dreyer, Rosenkranz, and Droop, Hanover.*

327. Water-meter, for domestic use.
Dreyer, Rosenkranz, and Droop, Hanover.

327a. Patent Water Gauge for steam boilers, independent of level or distance. *John Nicholas.*

This instrument is for indicating in an office or ship's cabin the quantity of water in the boiler or other vessel to which it is attached. The boiler may be any distance from the office, and upon any relative level. The small tank represents a portion of a boiler to which the stand pipe is attached; in the centre of the stand pipe is a brass tube, open at the top into the steam space, and communicating at the bottom with the right-hand union. The left-hand union opens directly into the water space. The right-hand union is connected by a lead pipe with the top part of the gauge glass, the other by a similar tube with the bottom of the glass, forming a continuous tube, one end of which is open to the steam and the other to the water space. This system is now entirely filled with water, which will always have the same level inside the brass tube as in the boiler, and any movement in the boiler will cause a corresponding motion in the brass tube, such movement being continuous throughout the system. A small quantity of oil is placed in the gauge to show readily this movement, and the line of contact in the glass tube represents the position of the water in the boiler.

327b. Patent Indicator, for tanks or reservoirs.
John Nicholas.

This gauge is similar to that last described, but the atmosphere giving comparatively a constant pressure the stand pipe can be dispensed with. The brass tube referred to in the previous description may be seen in the tan

attached. It is not necessary to pierce or employ a tank when attaching one of these gauges, and the small pipes can be laid in the walls in a similar manner to gas tubes. In some cases one tube is sufficient, the water column being balanced by mercury in a metal tube at the back of the gauge. This gauge is suitable for tanks upon the roofs of mansions or hotels, where engines are used for pumping.

327c. Patent Indicator for Artesian or other deep wells, or ships' bilge-well. *John Nicholas.*

This instrument indicates the quantity or depth of water in a deep well or pit, or the quantity of water in any vessel, as a ship's bilge, &c. It consists of an elastic chamber at the bottom of the well, connected with a glass tube and scale by a small lead pipe. This pipe and chamber are filled up with coloured liquid until it can be seen at O on the scale, the well being empty at the time. Any pressure put upon the now distended chamber presses forward the liquid along the glass tube, thus showing the depth of water above the chamber.

328. Indicator.

Dreyer, Rosenkranz, and Droop, Hanover.

329. Apparatus for determining the capacity of Cartridge-cases as far as 20 cub. mm. *A. Bonsack, Berlin.*

330. New Volumeter, consisting of A. Sauer's burette, a second glass piece, stands and tubes.

(Compare Fresenius, "Zeitschrift für analytische Chemie," xiv. heft. 3 and 4).

Berggewerkschafts-kasse at Bochum, Dr. Heintzmann.

331. Model of a Gas Meter of ancient construction, with glass sides.

School for Industry at Halle (Dr. Kohlmann, Director).

V. MEASUREMENT OF MASS.

A. Balances.

333. Balance, with double column, 20-inch beam, fitted with steel knife edges working on agate planes, to carry 5 lbs. in each pan, and turn distinctly with ·01 grain. Fitted with apparatus for moving sliding weight without opening glass case. As made for the Warden of Standards, for comparison of standard of standard weights. *L. Oertling.*

334. Balance, with double column, very light beam, 10 inches long, fitted with agate knife edges and agate planes, to carry 30 grains in each pan, and turn distinctly with ·001 grain, with apparatus for moving sliding weight. *L. Oertling*

335. Balance, with 14-inch beam, fitted with agate knife edges and agate planes, to carry 1,500 grains in each pan, and turn distinctly with ·001 grain. *L. Oertling.*

336. Balance, with 16-inch beam, fitted with agate knife edges and agate planes, to carry 2 lbs. in each pan, and turn distinctly with ·02 grain. *L. Oertling.*

337. Balance, with triangular beam, $6\frac{1}{2}$ inches long, fitted with agate knife edges and agate planes, to carry 3,000 grains, and turn distinctly with ·01 grain. *L. Oertling.*

338. Balance, with beam $6\frac{1}{2}$ inches long, fitted with agate knife edges and agate planes, to carry 2,000 grains in each pan, and turn distinctly with ·02 grain. *L. Oertling.*

339. Portable Assay Balance, with 6-inch beam, to carry 30 grains in each pan, and turn distinctly with ·001 grain. *L. Oertling.*

340. Balance, constructed by H. Olland, of Utrecht, to weigh bodies up to 40 kilogrammes.

Prof. Dr. P. L. Rijke, Leyden.

This instrument is furnished with a double system of "fourchettes," directed by a rod 0·6 m. long. A difference of 1° in the point of equilibrium answered to a difference in weight of—

9·5 m. gr.	when the	weight was	20	kilogrammes.
10·5	„	„	50	„
13·8	„	„	73	„

With weights of about 50 kilogrammes, in a series of experiments under favourable conditions, between each of which the balance was set at rest, numbers not differing in the average by more than 0°·03 were obtained. When conditions were less favourable, the differences amounted to 0°·26, and only reached 0°·94 when the conditions were altogether unfavourable.

341. Balance, charge up to 500 grammes in each pan; sensible to $\frac{1}{10}$ part of a milligramme with its full charge.

Beckers Sons, West Zeedyk, Rotterdam.

This balance is furnished with agate knives, and all bearings run on agate planes; it has a rest for pans and beam, and apparatus with adjustable shelf for taking specific gravities. The beam is divided in $\frac{1}{10}$ part of a milligramme. Sets of weights from 500 grammes down to 1 milligramme. Three riders.

342. Analytical Balance, on plan suggested by Professor Dittmar, Anderson's University, Glasgow, for a charge up to 100 grammes in each pan.

Beckers Sons, West Zeedyk, Rotterdam.

This instrument shows a new method for displacing the centre of gravity of the beam, and for weighing up to 110 milligrammes by means of riders. The two riders form a part of the balance, with plunger for displacing exactly 10 grammes of water at 15° C. for taking specific gravities of liquids. Sets of weights.

343. Balance, with drawer and eccentric for lifting, movable pans, set screws and level, charge up to $1\frac{1}{2}$ kilos. in each pan, sensible for 20 milligrammes with its full charge.
Beckers Sons, West Zeedyk, Rotterdam.

344. Balance, charge up to 1 kilo. in each pan, sensible for 20 milligrammes with its full charge.
Beckers Sons, West Zeedyk, Rotterdam.

348-9. Frerich's analytical **Balance,** capable of carrying 2,000 grms. with rider movements and a set of gramme weights.
F. Sartorius, Göttingen.

350. Analytical **Balance,** capable of carrying 500 grms., and a set of gramme weights. *F. Sartorius, Göttingen.*

351. Analytical **Balance,** capable of carrying 200 grms., with a set of gramme weights. *F. Sartorius, Göttingen.*

352. Frerich's analytical **Balance,** with contrivance of weighing by means of torsion. *F. Sartorius, Göttingen.*

353. A Pair of Russian Scales.
Bennet Woodcroft, F.R.S.

354. Test Balance capable of carrying 20 grammes in each scale. *Edouard Sacré, Brussels.*

The bearings are taken off the knife edges when the balance is at rest. With 20 grammes the balance is affected by the 750th part of a milligramme. With 2 grammes it is affected by the 7,000th part of a milligramme.

357. Printing Beam for Weighing Machine, admitting of the registration of each weighing. *M. Chameroy, Paris.*

This method of checking is applicable to all weighing machines in the nature of the steel-yard. It would be found useful at custom houses, depôts, markets, railway stations, works, and other similar places.

Its advantages are :—

1. The affording of a record, by means of a printed impression on a special ticket, of the exact amount of the weight as determined by the machine itself.

2. The facilitating of the reading of the weights, either on the ticket or on the scale beam.

3. The preservation of an exact record of weighings, the authenticity of which is thus ensured.

358. Physical Balance, weighing up to five kilogrammes.
Hugo Schickert, Dresden.

359. Physical Balance, weighing up to 200 kilogrammes.
Hugo Schickert, Dresden.

363. Fine Assay Balance for weighing 20 grammes, turning with 1/100 mg. *G. Westphal, Celle.*

364. Large Balance for determining the specific gravity of liquids. *G. Westphal Celle.*

365. Large Balance used in the **Manufacture** of **Sugar.** *G. Westphal, Celle.*

366. Small Balance for determining the specific gravity of liquids. *G. Westphal, Celle.*

367. Pharmaceutical Balance, for simple chemical operations. *G. Westphal, Celle.*

370. Balance for chemical and physical purposes.
C. Staudinger and Co. (F. W. von Gehren), Giessen.

These three instruments, together with No, 368, and 369 are chiefly used in forestry and agriculture.

Balance of the firm's own construction; capacity of weighing, one kilogramme on each scale; sensibility at this weight, 0·4 milligr. The balance is made of one piece of wrought (not cast) brass, and gilded. The centre and terminating edges consist of steel, and all supports of hard stone. The weight of the beam with edges is = 793 grammes; flexion of the beam at 1 kilogr. weight on each scale = 0·14 mm.; at 1,500 kilo. weight = 0·028 mm.; at 2·000 kil. weight = 0·042 mm. at 3·000 kil. = 0·070 mm. A permanent flexion has not been observed at such a weight.

375. Ten Plates of Rock Crystal for Balances.
Hermann Stern, Oberstein.

376. Chemico-physical Balance, executed by Ch. Jung, in Giessen.
Collection of Physical Instruments of the University of Giessen (Prof. Dr. Buff).

By shortening as much as possible the beam (balance) these scales offer the advantage of great flexibility and sufficient rigidness to weigh accurately from 250 grammes to $\frac{1}{10}$ milligrammes.

377. Analytical-balance, executed by Stollenreuther.
University of Munich.

379. Standard Weights in Glass, executed by Stollenreuther. *University of Munich.*

381. Model of a Balance for determining the quality of grain, adjusted according to the directions of the Imperial German Commission for Standard Weights and Measures, with a corn measure of 1 liter capacity. *Reinhold Löhmann, Berlin.*

The manner of adjusting the several parts, as well as the successive series of applications of the same, is illustrated and facilitated by an explanation, with sectional and cross-sectional drawings, accompanying the model.

The practical employment and use of the apparatus for scientific and technical industries, in the first instance, and next for the solution of national-economical problems, will be demonstrated by two continuous memoirs, published by the Imperial Commission for Normal Weights and Measures.

382. Model of a Centesimal Weighing Machine, with glass platform. *Dr. Kohlmann, Halle.*

384. Model of a Decimal Weighing Machine, with glass platform.

Physical Institute of the University of Halle (Prof. Knoblauch, Director).

386. Beam Balance with equal arms, sensibility 1 : 200,000. *Kleemann, Mechanical Engineer, Halle.*

390. Beam Balance, for educational purposes. *Alex. Bernstein and Co., Berlin.*

The steel-yard, for educational purposes, has contrivances for demonstrating the different peculiarities of a scales-beam, or balance, namely, displacement of the centre of gravity, lifting and grinding of the principal nut, unequal lengths of levers, non-parallelism of the knife edges, and position of *one* terminal knife edge extraneous of the level of the two other knife edges.

388. Small Decimal Balance, for educational purposes. *Alex. Bernstein and Co., Berlin.*

The decimal balance for instruction in schools has on each prism a scale so that the influence of the weight of each prism can be shown by itself.

389. Analytical Balance. *Alex. Bernstein and Co., Berlin.*

The analytical balance has a capacity of bearing 500 grammes, and when fully weighted a sensibility of $\frac{1}{10}$ mgr.; it has a perforated gilded brass beam with axes of agate and pans with arrangement for releasing all knife-edges, stop balance with pencil, and sliding-weights movement.

389a. New Balance for a Laboratory, carrying three kilogrammes in each pan, and turning with five milligrammes. *Deleuil, Paris.*

When it is not weighing, the beam is supported free of the knife edge, as in other accurate balances; vessels 25 centimetres in diameter can be placed on the pans, also vessels with long necks, and flasks of 1-2 litres capacity. By the aid of the second pan, the specific gravity of very bulby bodies can be taken.

390a. Self-Acting Balance for Galvanic-plastic purposes. *Alex. Bernstein and Co., Berlin.*

The scales for galvano-plastical purposes is so constructed that the conduction is interrupted by self-action as soon as a precipitate (deposit) of a certain weight has been obtained.

391. Balance for Blow-pipe Experiments, in a case. with weights. *Alex. Bernstein and Co., Berlin,*

The scales are for blow-pipe experiments; they have steel axes, and pans of agate, two scales of horn, two pairs of gilded little bowls, one bowl with hook for the determination of specific weights, and a set of weights from 1 gr. to 1 centigr. of silver; from 1 centigr. to 1 milligr. of aluminium, and the fraction milligr. of quills.

392. Gold Assay Balance.

Alex. Bernstein and Co., Berlin.

The gold-alloy scales have a bearing capacity of 5 grammes, and are provided with axes of agate and pans, and indicate, when fully weighted, $\frac{1}{20}$ milligr.

B. Steelyards.

332. Roman Steelyard or Statera, of bronze. It was found in the year 1855, during building operations at Watermoor, a suburb of Cirencester, Gloucestershire.

Professor A. H. Church.

The beam, which is nearly 17 inches long, may be reversed, and it is consequently divided along both its upper and under edges. When the fulcrum nearer the head of the beam is employed objects can be weighed more than twice as heavy as those which can be accommodated when the beam is suspended by the other hook. To the head of the beam is attached a chain, branching below into two parts, each terminated in bold hooks adapted for grasping soft and bulky articles. This steelyard is a very good example of its kind. The locality which furnished it was the site of the Roman city of Corinium or Durocornovium, which has yielded an immense number of Roman remains, many of which are preserved in the local museum.

378. Balance for Weighing in Vacuo, on von Jolly's principle. *University of Munich.*

383. Model of a Roman Balance, with sliding weight of 75 grammes, and stand.

Physical Institute of the University of Halle (Professor Knoblauch, Director).

C. Weights.

346. Six Standard Weights derived from the axial standard of length. *Prof. Hennessy, F.R.S.*

One of these weights is equivalent at 15° centigrade to a cube of distilled water whose side is the one hundred millionth part of the earth's polar axis. The others are submultiples of this weight, and the system is suggested in connexion with the axial standard proposed by Professor Hennessy.

360. Physical Weights. *Hugo Schickert, Dresden.*

361. Eight Sets of Weights, for analytical purposes.

G. Westphal, Celle.

The first of these weighs from 1 kilogramme downwards, the second from 500 grammes downwards, the third from 100 grammes, the fourth, fifth, and sixth from 50 grammes, the seventh from 10 grammes, and the eighth from 0·5 grammes downwards.

362. Standard Weights, adjusted and gilt.

G. Westphal, Celle.

These consist of a 1 kilogramme weight, a set of weights weighing from 1 kilogramme downwards, and a set of standard weights with pin adjustment weighing from 500 grammes downwards.

362a. Box of Weights, containing two kilos. and fractions of a kilo. *Deleuil, Paris.*

362a. One Case of Weights and Measures.

Set of weights from 1 kilogramme to 1 milligramme.

Set of weights from 50 grammes to 1 milligramme.

Set of weights from 1,000 grains to $\frac{1}{100}$ grain.

Set of weights for assaying silver, 1,000=1 gramme, in circular ivory box.

Sets of weights of rock crystal (one spherical set), from 50 grammes.

Set of measures from $\frac{1}{2}$ litre down.

Sikes' hydrometer, as supplied to the Honourable Board of Inland Revenue.

Bates' saccharometer, as supplied to the Honourable Board of Inland Revenue.

Set of petroleometers for testing liquids of 650 to 900 specific gravity.

T. Oertling.

262b. Iridio-Platinum Standard Kilogram.

Johnson, Matthey, and Co.

374. Sets of Weights and single Weights from 1 kilogramme, made of rock-crystal; amongst them some which have been examined and marked with an index error by the Imperial Commission for regulating Standard Weights and Measures at Berlin. *Hermann Stern, Oberstein.*

The weights, as well as the measures of quartz or rock-crystal, were many years ago recognised as the best and most correct; but no one has, up to this time, executed them in such a manner as to afford institutes an opportunity of procuring them; which want has now been supplied by the exhibitor.

The other objects of agate are such as are produced by the Oberstein-Idar grinding and polishing mill, and can be employed in different kinds of machinery.

387. Set of Pharmaceutical Weights from 0·01 grammes to 200 grammes (19 pieces).

Kleemann, Mechanical Engineer, Halle.

D. Instruments for determining Specific Gravity.

347. Tangential Balance for measuring the density of liquids and solids by the angle of inclination, read on a divided circle down to two minutes, thus giving the third decimal of specific gravity; made by Oertling, of London.

Prof. Carl Wenzel Zenger, Prague.

355. Hydrostatic Balance, by Ramsden; with **Weights,** by Robinson, presented to the Royal Society by Lady Banks.
Royal Society.

368. Xylometer (cylindrical form), with brass cylinder.
Zimmer Brothers, Stuttgart.

369. Xylometer of Glass, prismatic form.
Zimmer Brothers, Stuttgart.

These instruments are chiefly used in the management of forests, and for agricultural purposes.

The xylometer with brass cylinder (No. 1368), as well as the prism-shaped glass xylometer (No. 6369), are employed for exact scientific examinations, especially for the cubature of irregularly-shaped pieces of wood, and for determining the specific weight of wood.

With apparatus, No. 1369, cuneiform pieces of wood which have been split out from the heart in the direction of the pith rays, and therefore contain proportionate parts of all veins of wood, can be quickly and exactly examined.

With both apparatus it is possible to read on the scale accurately down to 5 cub. centimeter (5 grammes water).

(See " Holzmessekunst," by Prof. Dr. Baur, Hohenheim.)

371. Hydrostatic Indicator Balance for determining the specific gravity of liquids, constructed, according to the directions of the exhibitor by Böhm, and Wiedemann, at Munich.
Prof. Dr. W. von Bezold, Munich.

This balance enables to be read at once the specific weight of the liquid contained in the small cylinder. Care, however, must be taken that the floating body is always entirely immersed in the fluid, and that on the other hand the pointer does not move beyond the division on the arc in the direction towards the negative side. This is the case with liquids whose specific weight is smaller than 1, and only then when the free arm of the scales has been loaded with the heavier counter-weight, in which case the number on the arc indicated by the pointer gives at once the specific weight.

With liquids which are heavier than water the lighter counter-weight II. must be used, and 1 to be added to the number read on the graduated arc.

372. Densimeter of Major Bode's construction, for determining the specific gravity of all sorts of powder.
A. and R. Hahn, Cassel.

The densimeter is the only existing instrument with which the specific weight of all sorts of gunpowder (prismatic powder, powder-cakes, fine and coarse grained powder, &c.), can be easily determined, in quantities of 50 to 250 grammes, with the most perfect accuracy.

It is constructed by Major Bode.

This apparatus consists of a reservoir with bolt, two gutta-percha tubes, and a clamp.

1. The reservoir is formed by a steel capsule, with air tight fitting lid.

By means of the bolt the lid of the steel capsule will be screwed fast on this.

The contents of the reservoir are measured so in the clear that a prismatic powder grain can be easily placed in it.

Lid and steel capsule are vaulted, in order to accelerate the evacuation of the air by pumping.

In the steel capsule there is on the upper part, in the lid on the lower part, an air-tight fitting cut in cock. The reservoir communicates with these cocks by means of two channels, which, for fine-grained powder, are shut off by a steel tinplate filter, the holes of which have a width of 0·3 mm. The two tubes, 1 and 2, are screwed air-tight on the plugs of the two cocks 1 and 2. At the upper ends of both tubes funnels of glass are squeezed in for more convenient filling and emptying of the mercury. The shorter tube, No. 1, of about 600 mm. length, carries in the centre a glass-tube, about 200 mm. long, divided into millims, and can, just above this tube, be closed air-tight by means of a screw cramp. The interior diameter of the tube No. 1 is about 9 mm., whilst that of tube No. 2, which is about 2,500 mm. long, measures only about 5 mm. The gutta-percha tubes are spun over on the outside.

Reservoir and tube 1 are fastened in a wooden frame; funnel 2 is in a wooden lining.

This precaution has been taken for the reason that the temperature of the mercury and of the apparatus should be altered as little as possible during the operation by the warmth of the hands. By means of two strings, which run over rollers fastened in the ceiling of the room, funnel 1 and funnel 2 can be pulled up or down at pleasure.

As auxiliary apparatus are furthermore required :

1. A thermometer, by means of which, previous, during, and after the filling in of the mercury, the temperature of the same will be ascertained.

2. A fine pair of scales indicating as much as 0·001 grammes, with a bearing capacity of 6 kilos. (each scale 3 kilos.)

3. A barometer for determining the pressure of the atmosphere at the place of operation.

4. A wooden scale, 1 m. long, with a pointed steel sole, and a sledge for exactly measuring the difference in the level of the mercury menisci in the two tubes 1 and 2.

Theory of the Densimeter.

Let the weight of the reservoir be, with the tubes screwed off, but inclusive of the connecting piece screwing the capsule and the lid together, = R grammes. After the reservoir has been evacuated, and filled with mercury, let the weight of the same be, at t° temperature of the chemically pure mercury = T grammes.

Consequently the contents of the reservoir filled by the mercury amount to—

$$I = \frac{T - R}{13{\cdot}59(1 - 0{\cdot}00018\, t^\circ)} \text{ cub. centim.}$$

If now P grammes powder be filled into the reservoir, and the latter exhausted of air, and thereupon filled again with mercury, the same will weigh, at &° temperature, only T^1 grammes consequently amounts the volumen of the P. grammes powder, at t° temperature,

$$V = \frac{T - T' + P}{13{\cdot}59\ (1 - 0{\cdot}00018\ t^\circ)},$$

consequently the specific weight of the powder to be examined

$$\frac{V}{P} = \text{specific weight} = P\,\frac{13{\cdot}59\,(1 - 0{\cdot}00018\, t^\circ)}{T - T^1 + P}.$$

The following examples will serve as illustration :

The specific weight of chemically pure mercury amounts at

0° Cels. = 13·59 ; 10° Cels. = 13·57 19° Cels. = 13·55 ; 27° Cels. = 13·53
5° Cels. = 13·58 ; 15° Cels. = 13·56 23° Cels. = 13·54.

Example 1.

T = the reservoir filled with mercury weighs at 19° Cels. = 1091·6
R = the empty reservoir - - - - = 329·6

Q = T − R. Consequently mercury 762·0 grammes.
Consequently contents of the reservoir at 19° Cels.

$$I = \frac{T-R}{13{\cdot}59\,(1-t\,0{\cdot}0018)} = \frac{762{\cdot}0}{13{\cdot}55} = 56{\cdot}236 \text{ cub. centim.}$$

If now 60 grammes (= P) gunpowder is filled into the reservoir, and the remaining space of the same with mercury, we obtain
611·6 grammes ($=T_1$)

Reservoir empty = 329·6
60 grammes powder = 60·0

R + P = 389·6 deducted,

remains Q = 222.0 grammes weight of the mercury filling the intervening space, occupying at 19° Cels.

$$I = \frac{222{\cdot}0}{13{\cdot}55} = 16{\cdot}444 \text{ cub. centim.}$$

Consequently volume of the 60 grammes powder = 56·236 − 16·444
V = 39·792 cub. centims.

$S = \frac{P}{V}$ = consequently specific weight of the 60 grammes gunpowder

$$\frac{60}{39{\cdot}792} = 1{\cdot}507$$

Example 2.

If a powder prism weighs 42·0 grammes at 190° C. weight of reservoir, powder prism and mercury = 808·4 grammes.

Reservoir empty 329·6
42 grammes powder 42·0

371·6

consequently of 808·4
371·6 deducted,

= 436·8 grammes weight of mercury,

or $\frac{436{\cdot}8}{13{\cdot}55}$ = 32·236 cub. centim. occupied by these 436·8 grammes.

Consequently volume of the 42 grammes weighing powder prism = 56·236 − 32·236 = 24·0 cub. centim.

Thus, specific weight of the powder prism = $\frac{42{\cdot}0}{24{\cdot}0} = 1{\cdot}75$

General Formula.

$$S = \frac{P}{V} = \frac{P}{I-I^1} = \frac{P}{\dfrac{T-R}{13{\cdot}59(1-t\,0{\cdot}0018)} - I^1} \text{ or } I^1 = \frac{Q}{13{\cdot}59\,(1-t^\circ\,0{\cdot}0018)},$$

$$S = \frac{P\,[13{\cdot}59\,(1-t\,0{\cdot}0018)]}{T-R-Q^1}. \qquad \text{Since } Q^1 = T^1 - R - P$$

$$S = \frac{P\,13{\cdot}59\,(1-t\,0{\cdot}0018)}{T-T'+P}$$

The extension of the examples 1 and 2, therefore, is essentially facilitated:

Example 1.

Given P = 60 gr. $t = 19°$ C., consequently 13·59 (1 − 19 − 0·0018) = 13·55

T = 1091·6 grammes, $T^1 = 611·6$ grammes.

$$\text{Thus } S = \frac{60·13,55}{540} = 1·507$$

Example 2.

Given P = 42 grammes $t = 190°$ C.,

consequently specific weight of mercury = 13·55.

T = 1091·6 $T^1 = 808·4$

$$\text{Thus } S = \frac{42·13,55}{325·2} = 1·75$$

Because the expansion coefficient of the reservoir made of steel is different for changing temperatures from that of the mercury, it will be necessary for determining once for all empirically the weights of Tn for ±0, +5, 10, 15, 20, 25, 30, 35° Cels., to calculate the required cubical contents of the reservoir = Vn, to interpolate them graphically, and to embody them from degree to degree in a table.

Directions for Use of the Densimeter.

The temperature of the mercury is determined and noted before, after, and during the period of operation. For that purpose it is advisable to employ a thermometer composed of a very fine glass tube, which admits of being inserted in the gutta-percha tube No. 1, which has been filled up to the aperture of the funnel.

The mercury in funnel 1 will show, on account of the friction and consequent heating, 1 − 3° more heat than that in funnel 2. This difference is, however, equalised in a very short time.

During the operation the apparatus must only be touched on the wooden lining, in order to avoid as much as possible any variations in the temperature which may be caused by the warmth of the hands. The powder to be tested must be of nearly the same temperature as the mercury to be employed, for which purpose it will be best to keep both before the testing operation for several hours in the same room. The reading of the barometer which indicates the pressure of the atmospheric air must be noted down.

1. *Momentum.*

The two tubes 1 and 2 are screwed air-tight to the reservoir, the two cocks are opened, and the apparatus fastened in the wooden frame with vertical position of the tube No. 1.

Thereupon the funnel T″ is lifted to the level of T′ (upon + 760 mm.), and chemically pure mercury poured into the funnel T″, until both funnels are filled with mercury to a height of about 20 mm. The mercury will then stand 760 mm. high above the (±0) point of the reservoir; consequently the pressure upon the highest point of the reservoir will be altogether two atmospheres (1 atmosph. pressure corresponding in the mean to 760 mm. mercury height).

Under this pressure the air in the reservoir will for the greatest part be already forced up, and in fact in the direction towards funnel 1.

2. *Momentum.*

Now the cramp screw-piece is attached below the funnel 1, and above the glass tube in the centre of the hose 1 filled with mercury, and the latter shut off

air-tight at a height of about +600 mm. Then funnel 2 is sunk to about 1,000 mm. below the zero point of the reservoir. The mercury level will thereupon sink below the reservoir. In case reservoir and hose 1 were already exhausted of air, the difference of the level of both the mercury menisci will be exactly as much as indicated by the barometer, otherwise the difference will be smaller. All the mercury then flows back from the reservoir, &c. into the funnel 2, for which reason the same must have a sufficiently large space of capacity, and must be sunk carefully, not too quickly. Cock No. 1 is then shut, funnel No. 2 lifted above the zero point of the reservoir, and the latter, which in the most unfavourable case will contain only extremely rarified air, filled by the same; then cock 1 is opened, and the cramp at the hose No. 1, so that the mercury in the funnel No. 1 can rise again. This exhausting of the air is repeated a second time if necessary.

For testing whether the reservoir is entirely or sufficiently exhausted of air, funnel 2 is sunk so far until its mercury level has reached about 400 mm. below the zero point of the reservoir. Now occurs a Toricelli's vacuum in hose 1, and the mercury meniscus is seen in the glass tube.

If there were still air in hose 1, the level-difference in the hoses 1 and 2 will be smaller than the height indicated by the barometer for the day in millimeters. In this case the operation mentioned before is repeated. In all cases will, at the utmost at a position again of funnel 2 at about −440 mm., the difference of the level of both the mercury menisci be smaller by 2−3 mm. than the indication of the barometer for the day. If the difference in the variation of the levels should show itself equal to the height of the barometer, what may be easily ascertained by the scale, if its at the lower end pointed steel sole touches the mercury in funnel 2, by adjusting the slider fastened at the height indicated by barometer at the upper meniscus in the glass tube; the pressure at the upper part of the reservoir will then be—

$$\left.\begin{array}{l}1 \text{ atmosph. air pressure} \\ -\ 1 \text{ atmosph. mercury pressure}\end{array}\right\} = 0 \text{ mm.}$$

consequently the reservoir exhausted of air.

But in order to employ a further powerfully-acting means for exhausting the air, so far as this should not have been accomplished already, the funnel 2 is lifted as high as possible up to about $2\frac{1}{2}$, 760 = 1,900 mm., thereby the very small quantity of air still present will be forced into the hose 1 under $2\frac{1}{2}+1=3\frac{1}{2}$ atmospheric pressure, and will ascend either towards the hose 1, or occupy only a small and practically insignificant place, of 0·001 to 0·0001 cub. cent. by shutting off the cocks 1 and 2.

The raising and lowering of hose 1 and 2 is performed by pulling or slackening of the cords running over the rollers fastened into the ceiling of the room.

It may now be supposed that the air is completely exhausted from the reservoir, and that its vacuum is completely filled with mercury. At all events the hydrostatic air pump of 0 to 3·5 atmosph. pressure, attached to the apparatus in the simplest manner possible, will act much more powerfully than any other air pump, in which the so-called injurious space in the ventilator of the piston makes it impossible to increase the suction action to 0 atmosph. pressure.

Finally, the two cocks 1 and 2 in the mercury are shut off, the temperature of the latter being determined, the two hoses 1 and 2, which have previously been carefully emptied, are unscrewed, the reservoir cleaned of the mercury globules sticking to it (especially in the parts of the screw and the interior channel-openings of the cocks), and the weight of the reservoir, including bolt, determined with mercury.

Determination of the Specific Weight of the Powder to be Tested.

The prisms or pieces of cake, or the coarse or fine-grained powder to be tested, are accurately weighed on a scale at 0·01 grammes.

The powder prisms of 25 mm. height, 40 mm. measured across the edges, 35 mm. on two sides, with channels each of 4·2—4 f mm. wide, or one channel 10 mm. wide, weigh, as a rule, at a specific weight of 1·6 to 1·8, from 36 to 44 grammes.

Of grained powder so much is weighed that the steel lid can be easily fixed on the reservoir, and fastened with the bolt, consequently about 50 grammes in case of a small reservoir with about 76 cub. cent. contents of capacity, or 200 gr. in case of a larger reservoir of about 217—226 cub. cent. capacity. The quantity of powder weighed is filled into the reservoir; this is then closed, the two hoses 1 and 2 are screwed on, and the operation is thereupon proceeded with as detailed in the preceding explanations.

It must be observed hereby that the operation is very simple and expeditious, excluding every personal error, so that, consequently, the method, being based on scientific principles, is a thorough rational one.

It should cause no surprise if the momenta 1 and 2 must be repeated several times, when the powder has been filled in, in order to raise the difference of the level of the two mercury columns to the same height as the position of the barometer, as the large capabilities of the coal of the powder of absorbing the air is a notorious fact, and as also the moisture contained in the powder is to a very great extent evaporated in the form of aqueous vapour, or ejected by hydrostatic pressure and tension.

373. Mercurial Powder Balance, Major Bode's construction, for determining the specific gravity of prismatic and coarse-grained gunpowders. *A. and R. Hahn, Cassel.*

The mercurial powder scale supplants the alcohol or so-called "volu-metrical analyses method," and by means of this instrument the specific weight of the different sorts of powder, viz., 1, prismatic; 2, powder-cake; and 3, coarse-grained powder, can be exactly determined in quantities of 40 to 50 grammes.

380. Balance for Weighing in Vacuo.
Paul Bunge, Hamburg.

The vacuum scale is a duplicate of a similar scale made for the Physiological Institute at Kiel. For facilitating the evacuation it has been fitted into a small space of 5 inches diameter and 10 inches in height, which was only possible by the exhibitor's system of employing short balances (beams). The latter is 69 millimeters long, and is at a weight of 50 gr. sensible at the rate of $\frac{1}{20}$ mgr.

The use of the scales is as follows:—After the body which is to be weighed in the rarified space, or to be exsiccated, has been placed on the scales, and the evacuation or the exsiccation has been effected, the scale can be arrested and released by means of three corks fixed in the bottom plate by appropriately turning the same. All weights of 20 gr. to 0·01 gr. can be placed on or lifted off the frame supplying the weight scale. Lastly, a block can be slided along the whole length of a ruler in the line of the axis.

VI.—MEASUREMENT OF VELOCITY.

A. Logs and Current Meters.

393. Patent Log. Massey. For measuring speed at sea; in use in H.M. Navy.

Hydrographic Department of the Admiralty.

394. Patent Log. Walker. For measuring speed at sea.

Hydrographic Department of the Admiralty.

396. Current Meter, for measuring the velocity of currents in rivers at different depths. *Elliott Brothers.*

An endless screw on a spindle turns two wheels at the same time, the one recording every revolution of the blades by moving one division; the other indicating every complete revolution of the former.

397. Rery's Current Meter, constructed for measuring the velocity of currents in larger rivers. *Elliott Brothers.*

The spherical boss is so determined that it will displace just as much water, as to weight, as will balance the weight of all the parts which are fixed to the spindle, so as to reduce friction to a minimum. Although the apparatus is covered with glass, it has to be filled, before using it, with pure water to establish similarity of pressure inside and outside. After every experiment the water is removed and the spindle thoroughly dried. This form of current meter was used by Mr. Rery on the survey of the Parana and Uruguay rivers.

397a. Darcy Pilot Gauge or Current Meter, for determining the velocity of streams of water. *Prof. W. C. Unwin.*

The velocity is obtained by a single measurement, and no time observation is required. Used in Darcy and Bazin's researches on the flow of water in pipes and canals.

398. Ramsten's Patent Ship's Log. *Elliott Brothers.*

399. Water Meter, based on the principle of measuring the volume of water by recording its speed. *J. A. Muller, C.E.*

This water meter consists principally of an air and water-tight chamber or vessel, wherein moves a float, carrying two magnets of equal power, and fixed with their dissimilar poles in juxta-position to each other: the whole combination of the float and its spindle, together with the magnets, is made as near as possible equal to the density or specific gravity of water. The water in passing through this measuring vessel is forced to take a rotary motion, by means of a screen or a tongue, being a metal piece, put at a certain distance from the inlet opening, and parallel with and lying along the inner circumference of the measuring vessel. The top cover of the measuring vessel is properly dished out, so as to allow of two small soft iron armatures, fixed to a thin metal arm or needle, to be brought outside the vessel, as near as can be to the poles of the magnets inside; the metal arm or needle is fixed to a light spindle, carrying an archimedean screw, which further gears with the registering parts of the apparatus. It is evident that the water in passing through the measuring vessel, or rather alongside the same, communicates its motion to the water inside the measuring vessel, which motion is also communicated to the float and magnets, and lastly to the needle and worm spindle and further

gearing. It is plain that this meter really registers the true velocity of the water, and taking, moreover, in consideration the lightness of its different parts and the transmission of the speed of the float by means of magnets, it will be found to be a very correct and sensitive meter, of simple and durable construction.

399a. Water-meter, with electrical numbering apparatus, according to Amsler's latest construction. (*See* description.)
Polytechnic School at Aix-la-Chapelle, O. Intze.

If the instrument makes 100 revolutions the electric current will be closed by a contact, and the chime work will be kept in motion during some revolutions of the instrument; it will not be necessary, therefore, in measuring the velocity in water-courses, to pull the instrument out of the water, but only to note the time which passes from one signal to the other. By experiments it must be ascertained what velocities of the current of the water correspond to certain intervals of time of the electric signals.

400. Patent Electric Velocimeter, invented by Francis Pastorelli, arranged for water currents, and for ascertaining the speed of vessels, or rate of their motion through water. It consists of three parts. *Francis Pastorelli.*

1. Four hemispherical cups are fixed to the end of four strong metal arms (at a distance of 90° apart) that radiate from a central boss, which are mounted on a horizontal axis at right angles in a framework of metal, or other material, so that they may freely revolve when placed in the water. The horizontal axis has fixed to it a point or piece of platina; upon this work pressing points or surfaces, which can be made of any form, circular or otherwise; each revolution of the axis causes a contact to be made.
2. The same receiving instrument, as used for the mining instrument.
3. A Leclanché battery, as used for the mining instrument.

The receiving instrument can be placed in any convenient position on board.

N.B.—No. 1. This part of the instrument is intended to be fixed at any desirable and convenient part of the vessel, or it may be arranged to throw overboard; under such conditions it will give more accurate indications than the logs now in use, for it is not affected like them in their motion by depth, or the increasing density of water; assuming that corrections be applied for force and direction of currents, with respect to the course or line of motion, I think the errors would not be found to exceed 5 per cent.

402. Apparatus for indicating the **Speed** of a **Ship** by the aid of **Electricity.** *Bennet Woodcroft, F.R.S.*

409. A Rhysimeter, without frictional parts, for measuring the speed of water or other liquids whether in pipes or open channels. *Alfred E. Fletcher, Liverpool.*

B. Anemometers.

408. An Anemometer, without frictional parts, suited to measure the speed of air or gases, even when highly heated, or when contaminated with smoke or corrosive vapours. Used by H.M. Inspectors of Alkali Works. *Alfred E. Fletcher, Liverpool.*

410. Lowne's Portable Air Meter, originally introduced by Casella. *R. M. Lowne.*

The indications of this instrument are obtained by means of a light fan which communicates motion to indicating wheels; the dial of the instrument is placed at right angles to the fan, and is supported by three pillars on a base, which also supports the tube containing the fan. The works are extremely sensitive, the first centres running in jewels, and the indicating parts can be thrown in or out of gear with the fan.

410a. Lowne's Patent Magnetic Anemometer, especially adapted for measuring currents of air, gases, and fluids in positions where delicate instruments would be subject to corrosion. *R. M. Lowne.*

The peculiarity of this instrument is, that the registering works are enclosed in an air-tight chamber, the connexion of the revolving fans with the works being made through a sheet of brass by magnetism. The fans carry a small bar magnet, and the first wheel of the indicating mechanism carries a piece of soft iron, so that when the fans revolve outside the plate of brass the soft iron revolves within by attraction and thereby moves the works.

410b. Lowne's Patent Colliery Air Meter, constructed expressly for use in mines. *R. M. Lowne.*

The external aspect and form of this instrument is that of the well known "Byron's Anemometer." The improvements consist of.—1st, a strong, light, and anti-corrosive fan; 2nd, a large clear dial; 3rd, the indicating parts are perfectly protected from dust and smoke, this being done by a practical mechanical arrangement; and 4th, a lever is placed in a convenient position to enable the observer to throw the indicating wheels in or out of gear with the fan.

410c. Lowne's Patent Magnetic Anemometer and Current Meter, for measurement of velocity of currents of air, gas, and fluids. *R. M. Lowne.*

In this instrument the registering works are enclosed in an air-tight chamber, the connexion of the revolving fans with the works being made through a sheet of brass by magnetism. Gymbals accompany this instrument, with direction vane, for use on board ship.

410d. Lowne's Patent Ventilation Anemometer, originally introduced by Stanley. *R. M. Lowne.*

This instrument measures the air by means of a fan wheel placed in a clear opening, without any obstruction from the registering apparatus, which is in a separate chamber on the same plane as the fans, so that the instrument is quite flat for the pocket; the whole of the works are of extreme sensitiveness, and the axes of the fans run in jewels, the indicating hands give the current that passes the fans in feet (after correction), and a lever above the dial throws the registering works in or out of gear with the fans.

410e. Mining Anemometer, for showing the velocity of currents in mines. *Elliott Brothers.*

410f. Biram's Anemometer. Improved for Coal Mines. *Francis Pastorelli.*

It consists of a broad brass ring; fixed to it is a metal frame which carries three divided circles; in the interior and centre of the ring is a spindle which carries eight vanes; on one end is an endless screw; this works a series of wheels, which give motion to the hands on the dials, which record the velocity of the air current every foot up to 100, 1,000 and 10,000 feet.

410g. Dickinson's Anemometer.

Joseph Casartelli, Manchester.

This anemometer consists of a fan, or plate, made of light material, suspended in a frame on delicate centres, having a balance weight attached to the top of the fan. To one side of the frame is fixed on pivots a quadrant opening out at right angles to the fan, and on it is marked the velocity of the current in feet per minute, as indicated by the angular rise of the fan upon which the current impinges. The advantage of the instrument consists in the fact that *it requires no timing* as required by every other instrument, and from actual experiment it is found as accurate as the most delicate instrument, and very convenient.

410h. Improved Biram's Anemometer.

Joseph Casartelli.

The improvement in this instrument consists in the fan being made of light material, thus greatly diminishing the friction, and rendering it a delicate and useful instrument.

410i. Biram's Patent Anemometer for ascertaining the current of air in mines, air flues, &c. *John Davis and Son.*

This anemometer registers up to 1,000 feet. At the bottom there is a tube in which a stick may be inserted, so that the experimenter can stand at a distance from the instrument, otherwise the current of air would be deflected by the body of the experimenter.

The vanes may at will be disconnected from the indices by means of a stud at the side, thus rendering the process of timing more simple and exact.

410k. Biram's Patent Anemometer for ascertaining the current of air in mines, air flues, &c. *John Davis and Son.*

The 4″ anemometer indicates up to 10 million feet. The size and angle of the vanes are calculated by mathematics and corrected by experiment, each instrument being corrected separately.

The registering apparatus consists in the 4 in. new anemometer of six small circles, marked respectively X, C, M, X M, C M, and M, the divisions on which denote units of the denominations of the respective circles; in other words, the X index in one revolution passes over its ten divisions and registers 10 × 10 or 100 ft.; the C index in the same way 1,000 ft.; and so on up to 10,000,000 ft.; so that an observer has only to record the position of the several indices at the first observation (by writing the lowest of the two figures on the respective circles between which the index points in their proper order), and deduct the amount from their position at their second observation, to ascertain the velocity of the air which has passed during the interval; this multiplied by the area in feet of the passage where the instrument is placed, will show the number of cubic feet which has passed during the same period.

The novelty in this anemometer is in its extreme portability and substantial workmanship; it is supplied with a lever which disconnects, at will, the vanes from the indices, thus rendering the process of timing more simple.

414. Edelmann's Anemometer with galvanic register.
M. Th. Edelmann, Munich.

416. Anemometer for determining the velocity of the air, and other gaseous currents in pipes and canals.
Moritz Gerstenhöfer, Freiberg.

C. CHRONOGRAPHS.

401. Apparatus for measuring the velocity of projectiles, and capable of recording several measures or lengths on one and the same trajectory and of the same projectile.
Antoine Joseph Gérard, Liége.

403. Ballistic Apparatus Chronoscope, with two pendulums, for ascertaining the speed of a projectile at any point of its trajectory, by measuring the time of direction of a portion of the trajectory; also for measuring portions of time between one tenth of a second and 25 seconds. *Lieutenant-General Leurs, Brussels.*

404. Electric Chronograph, for measuring the initial velocity of projectiles (space required, 0.50 square centimètres on the ground). *Le Boulengé, Liége.*

405. Electric Clepsydra, for measuring the period of time of the trajectory of projectiles (space required, 0.50 square centimètres on a table). *Le Boulengé, Liége.*

405a. Electro-Ballistic Apparatus, for determining the velocity of a projectile, with description of experiments and additional apparatus. *M. Navez, Paris.*

406. Electric Chronograph for the measurement of minute portions of time, &c. &c. *Lieut. H. Watkin, R.A.*

This instrument consists of two upright cylinders resting on a base of wood; between them, suspended by an electro-magnet, is a weight with projecting arms. The cylinder being connected with the secondary circuit of an induction coil, the circuit is complete with the exception of the small spaces on either side of the weight. When taking velocities of shot, the primary circuit is led through screens, constructed so that the current is broken and immediately made again during the passage of the shot. The gun being fired, the weights begin to descend; the shot in passing the first screen causes a spark to flash from one cylinder to the other through the weight; then having been previously smoked register of a white spot the position of the weight at that instant. As the weight continues to descend the same result is obtained at the next screen, &c. &c. Adjacent to the cylinder is a time scale divided into thousandths of a second, subdivided by a novel vernier into hundred thousandths of a second, by which the absolute time taken by the shot between the screens is easily read off.

407. The Clock-Chronograph, contrived for the purpose of measuring the time occupied by projectiles in passing over a

succession of equal spaces, with a view to determine accurately the resistance of the air to their motion. *Rev. F. Bashforth.*

If the fly-wheel be spun by hand, and the markers be brought down, they will trace two uniform spirals on the cylinder; each marker is, however, under the control of an electro-magnet. When the galvanic current is interrupted, a record is made by the corresponding marker being suddenly drawn aside. The circuit of the lower electro-magnet is interrupted once a second by a clock beating half-seconds, which gives a scale of time. The circuit of the upper electro-magnet passes along the tops of all the screens, as is shown in the case of one screen. When one or more threads are broken in any screen, a record is made on the cylinder. Thus, when an experiment is to be made, the fly-wheel is spun briskly by hand, the markers are brought down, and the gun is fired. The times of passing the screens are recorded on one spiral, opposite a scale of time on the other. This instrument was used in making all the experiments referred to in "Reports on "Experiments made with the Bashforth Chronograph to determine the "Resistance of the Air to the Motion of Projectiles, 1865–1870," published by authority. Generally 10 screens were placed at intervals of 150 feet, but in the experiments with the Whitworth gun (p. 162), 16 screens were placed at intervals of 75 feet; some of these records are shown. For a full description of the chronograph, see Proceedings of the Royal Artillery Institution, Woolwich, for 1866, which description is also published separately.

407a. Chronograph for projectile experiments with the recording apparatus of Deprez. *Dumoulin Froment, Paris.*

411. Complete Apparatus for measuring the Velocity of Projectiles in the bore of a gun, and for measuring the speed of electricity. *Siemens and Halske.*

412. Vibration Chronograph, for measuring the time of descent on an inclined plane, executed according to Beetz, by M. Th. Edelmann, at Munich. (A description accompanies the object.) *Prof. Dr. Beetz, Munich.*

413. Edelmann's Apparatus for the descent of a falling Body accessory to Beetz's chronograph.
M. Th. Edelmann, Munich.

D. Strophometers.

395. Hearson's Patent Strophometer or Revolution Indicator, an instrument for showing at a glance, by the position of a pointer on a graduated dial, the number of revolutions per minute an engine is at the time making. *Elliott Brothers.*

415. Mercurial Gyrometer, or "orbit meter."
Royal Polytechnic Academy (Prof. Reuleaux, Director), Berlin.

The instrument indicates directly the angular velocity of an axle, shaft, &c., in figures showing the rotations per minute. The reading takes place on an alcohol column, which shows on one side a millimeter scale, and on the other the rotation numbers. The instrument is so arranged that the scale of the rotations has uniform graduation.

415a. Revolution Indicator, to show the rate at which machinery is working. *Frederick Guthrie, F.R.S.*

From the machinery an up-and-down motion is communicated to a piston of a pneumatic forcing pump. The compressed air escapes through a fine opening, and also exercises pressure on oil, water, or mercury, in a vessel provided with a manometer tube. The height of the liquid in the tube measures the rate at which the pump and machinery are working.

VII.—MEASUREMENT OF MOMENTUM.

417. Model of the Ballistic Pendulum, erected in the Royal Arsenal in 1814, and transferred to the Royal Military Repository in 1836. Weight, 7,740 lbs. Centre of gravity below centre of suspension 10·97 ft.; centre of oscillation below centre of suspension 11·88 ft. Scale ⅛th. *Major M. L. Taylor, R.A.*

418. Navy Electro-Ballistic Apparatus. *Major M. L. Taylor, R.A.*

419. Model of Ballistic and Gun Pendulum, as erected at Shoeburyness in 1858. Oscillating system of gun pendulum, weighs 37 lbs. 10·5 oz.; that of the block pendulum weighs 31 lbs. 8·25 oz. Scale, ⅛th. *Major M. L. Taylor, R.A.*

419a. Spring Balance, with arrangement for suspending the lever and the scales on steel springs.
Physical Institute of the University of Halle (Prof. Knoblauch, Director).

VIII.—MEASUREMENT OF FORCE.

420. Cement Testing Apparatus, for ascertaining the tearing strain of Portland and other cements, in sections of 1½ square inches. Originally designed for the Metropolitan Board of Works. **Press** for removing bricks from mould; and **Moulds** for making test bricks. *Patrick Adie.*

420a. Michele's Patent Cement Testing Machine. *De Michele, Rochester.*

The block to be tested is placed in the jaws prepared to receive it, the handle is then turned, which raises the weighted lever by exerting a pull on its short end through the medium of the cement block. When the leverage is so increased as to exert a force too great for the cement to sustain, it breaks, and the lever falls, leaving the main-pointer at the spot to which it had been raised. The arc along which the pointer moves is graduated to show the number of pounds of tensile strain applied. A suitable arrangement, when

the cement block breaks, prevents the lever from falling more than half an inch.

These machines are now in general use, nearly one hundred of them having been sent to different parts of the world. They are principally used by the leading royal and civil engineers in this country, and by a large number of contractors and cement manufacturers.

420b. Drawings of Machines and Apparatus for testing Materials. *Charles Jenny, Vienna.*

Five sheets of drawings, representing :—

1. Machine for testing, by means of traction and pressure, the elasticity and density (solidity) of materials.

The actual machine of the Imperial Institute was constructed by C. Paff in Vienna.

2. Testing machine for materials. Werder's system constructed for testing flexible elasticity and solidity. Executed by the Machine Factory Company, Kell & Co., at Nuremberg.
3. Testing machine for materials. Werder's system. Constructed for testing the elasticity of twisting and solidity. Executed by the Machine Factory Company, Kless & Co., at Nuremberg.
4. Machine and apparatus for ascertaining and determining the elasticity and solidity of wire, leather straps, thin ropes, &c.

Executed in the former workshops of the Imperial and Royal Polytechnic Institute.

5. Optical apparatus for determining the modulus and the limits of elasticity by the application of tractive force, pressure, flexible elasticity, and solidity.

The original apparatus of the Imperial Polytechnic Institute were constructed by G. Starke and Kammerer, mechanicians, at Vienna.

421a. An Attraction Meter. An instrument for measuring horizontal attraction. *Dr. Siemens.*

This instrument consists of two horizontal tubes of wrought iron, terminating at each end in a horizontal tube of cast iron. The first-named horizontal tubes are partially closed at their extremities, and communicate with the transverse tubes below their horizontal mid-section. The transverse tubes communicate also by means of a horizontal glass tube of 2 millims. diameter at a superior level to the former.

The whole apparatus being mounted upon three set screws is filled to the level of the half diameter of the transverse tubes with mercury, which mercury also fills the whole of the longitudinal connecting tube ; the upper halves of the cast-iron transverse tubes and the glass connecting tube are filled with alcohol, comprising, however, a small bubble of air, which can be made to occupy a central position in the glass tube by raising or lowering the set screws.

If a weighty object is approached to either extremity of the connecting tube, an attractive influence will be exercised upon the mercury, tending to a rise of level in the reservoir near at hand, at the expense of the more distant reservoir ; and this disturbance of level between the two reservoirs must exercise a corresponding effect upon the index of air in the horizontal glass tube, moving it away from the source of attraction. The amount of this movement must be proportional to the attractive force thus exercised. Variations of temperature have no effect upon this instrument, because the liquids contained on either side of the bubble of air are precisely the same in amount; and the total expansion of the liquids is compensated for by an

open stand tube rising up from the centre of the connecting tube through which the apparatus can be easily filled.

It is suggested that an instrument of this description may be employed usefully for measuring and recording the attractive influences of the sun and moon which give rise to the tides.

The instrument, which is of simple construction and not liable to derangement from any cause, would have to be placed upon a solid foundation with its connecting tube pointing east and west, records being taken either by noting the position of the index upon the graduated scale below, or by means of a self-recording arrangement through photography.

421b. The Bathometer. An instrument for measuring the depth of the sea without the use of the sounding line.

Dr. Siemens.

The total gravitation of the earth, as measured on its normal surface, is composed of the separate attractions of all its parts, and the attractive influence of each equal volume varies directly as its density, and inversely as the square of its distance from the point of measurement.

The density of sea water being about 1·026, and that of the solid constituents composing the crust of the earth about 2·763 (this being the mean density of mountain limestone, granite, basalt, slate, and sandstone), it follows that an intervening depth of sea water must exercise a sensible influence upon total gravitation if measured on the surface of the sea.

The bathometer consists essentially of a vertical column of mercury contained in a steel tube having cup-like extensions at both extremities, so as to increase the terminal area of the mercury. The lower cup is closed by means of a corrugated diaphragm of steel plate, and the weight of the column of mercury is balanced in the centre of the diaphragm by the elastic force derived from carefully tempered spiral steel springs of the same length as the column of mercury.

One of the peculiarities of this mechanical arrangement is, that it is parathermal, the diminishing elastic force of the springs with rise of temperature being compensated by a similar decrease of potential of the mercury column, which decrease depends upon the proportions given to the areas of the steel tube and its cup-like extensions.

The instrument is suspended a short distance above its centre of gravity in a universal joint, in order to cause it to retain its vertical position, notwithstanding the motion of the vessel, and vertical oscillations of the mercury are almost entirely prevented by a local contraction of the mercury column to a very small orifice. The reading of the instrument is effected by means of a glass tube on the top, which connects the upper surface of the mercury with a liquid of less density, the terminal extremity of which on a scale represents the depth.

Variations of atmospheric pressure have no effect upon the reading of this instrument; but a correction has to be made for variations of atmospheric density as affecting the relative weight of the mercury column, which correction might be avoided, however, in excluding the atmosphere.

From both the upper and lower surface of the mercury, and connecting the extremities of the column, the only necessary correction is that for the effects of latitude, which may be calculated as depths in fathoms, and tabulated for use with the instrument.

The readings of the instrument have been checked by actual soundings taken by means of Sir William Thomson's steel wire sounding apparatus; and the comparable results agree in all cases as closely as could be expected, considering that the sounding line gives the depth immediately below the

vessel, whereas the bathometer gives the mean depths taken over a certain area, depending for extent upon the depth itself.

It is thought that the bathometer may render useful service to the mariner in warning him of changes of depth long before reaching dangerous ground; and the position of a vessel, when no astronomical observations can be taken, may be ascertained by means of a bathometer, provided the contour lines of equal depths of oceanic basins were accurately laid down.

421c. Graphical Bathometer, after von Jolly.
University of Munich.

423. Apparatus for determining the **elasticity, strength of traction,** and **columnal strength** of woods and timber.
Prof. Dr. Nördlinger, Stuttgart.

423a. Apparatus used for experimenting on the Flexural and Torsional Rigidity of Solids, by Professor Everett, and described in the "Transactions of the Royal Society," 1866, p. 185. *Sir William Thomson.*

424. Apparatus for determining the relative **strength of flexure,** and the **elasticity** of woods and timber.
Prof. Dr. Nördlinger, Stuttgart.

425. Hydrostatic Apparatus for ascertaining the specific weight of woods. *Prof. Dr. Nördlinger, Stuttgart.*

425a. Registering Statical Gauge for Pressure in Guns. System of W. Paschkiéwitsh.
Captain W. Paschkiéwitsh, St. Petersburg.

426. Thurston's Testing Machine, invented by Professor Thurston, of Steven's Institute of Technology, Hoboken, U.S.A.

This machine is used for testing the limit of resistance, ductility, and homogeneousness of iron, brass, steel, and other materials of construction. By means of an ingenious but simple arrangement, a permanent diagram of the behaviour under varying conditions of the materials can readily be obtained.
W. H. Bailey and Co., Manchester.

426a. Machine for **measuring** the **slipping** between **hard surfaces** rolling in contact. *Prof. Osborne Reynolds.*

This machine was constructed for the purpose of verifying the conclusions of the exhibitor respecting rolling friction, and the existence of a certain amount of slipping between two smooth surfaces of different curvature, or different hardness, when the one rolls on the other under pressure. It has also been used to measure the slipping between the surfaces, when the one is driving the other against various resistances and at various speeds, as well as the wear of the surfaces.

The large rolling surface is of cast-iron, supported so that it can rotate freely, but otherwise rigidly fixed. For the smaller surface various materials have been used, that exhibited being of steel; this cylinder is supported so that while its axis is always parallel to that of the larger cylinder, it can be pressed against the larger cylinder with various degrees of pressure by means of a lever acting through friction rollers. Arrangements are made for recording the number of revolutions of both cylinders; and connected with

both spindles are driving pulleys and friction breaks on Appold's system, by means of which the force to be transmitted can be regulated.

An amount of slipping of not more than the one hundred thousandth part of the distance rolled can be measured with this machine.

The machine was constructed in Owen's College by Mr. Foster.

427. Phroso-dynamic Apparatus for testing wires, by Mr. Alcun. *M. Digeon, Paris.*

428. Von Jolly's Spring-balance.
University of Munich, &c.

428b. Pieces of Steel Cylinders, torn by traction in experiments made to ascertain the influence of mode of treatment on the mechanical properties of steel.
Imperial Technical Society in St. Petersburg.

Annexed is a report on the experiments. Out of a block of unforged soft cast steel were cut, in identical positions parallel to the axis, 16 bars which were treated in heat or forging in eight different manners, two samples in each way. The samples were then turned in shape of cylinders for traction proof, and for each of them determined elastic and permanent elongations for a series of increasing traction forces, density, hardness (by indentation), and other elements. Results indicated in annexed diagrams and tables.

IX.—MEASUREMENT OF WORK.

429. Dynamometer, graduated up to 100 kilogrammes by intervals of 200 grammes, and showing dynams in kilometres up to 981, each interval measuring two dynams nearly in absolute measure. *Prof. Hennessy, Dublin.*

430. Dynamometer graduated up to 10 kilogrammes, and giving absolute dynams in kilogrammetres up to 98, each interval measuring nearly one dynam in absolute measure.
Prof. Hennessy, Dublin.

431. Drawing of a Dynamometrical Apparatus, constructed in 1844 by the exhibitor, to measure the real horse-power of steam-boats. *Prof. Daniel Colladon, Geneva.*

This apparatus, approved by the Academie des Sciences in 1843, was, in the same year, adopted in the Royal Dockyard at Woolwich.

432. Richard's Patent Steam Engine Indicator, with Darke's Patent Detent and Cord Adjuster. *Elliott Brothers.*

By means of the detent, the paper cylinder is instantaneously set in motion or stopped by the movement of the pencil arm, as it is being applied or withdrawn, giving great facilities for taking a number of consecutive diagrams, also rendering its application to oscillating engines much more convenient.

433. Cooper's Patent Slide Valve Indicator. An instrument for ascertaining the relative position between the piston and slide valve of an engine at different points of the stroke.
Elliott Brothers.

434. Flexion Pandynamometer. An instrument designed to determine the work done by a steam engine, by means of the flexion of the beam. *G. A. Hirn.*

On the upper edge of the beam is a rigid wooden bar of the same length, resting in the centre on a fork which prevents it from swerving, fastened to one end of the beam with an iron rod, and free at the other end. To this extremity is attached a non-elastic cord, which passes round a pulley, fixed at the head of the beam, and is carried thence towards the centre, where it is wound round the axis of a very light needle.

It is evident, from this arrangement, that when the beam moves in either direction, the end of the wooden bar which remains rigid approaches to or recedes from the head of the beam. The cord consequently winds itself round, or unwinds itself from, the axis of the needle, and the deviation of the latter indicates the degree of flexion of the beam, multiplied if desired. At the end of the needle is fixed a pencil, which works on a small board placed above the beam. This pencil, at each double stroke of the piston, traces a closed curve, of which the ordinates indicate the successive degrees of flexion of the beam during the work. To graduate, once for all, the degree of flexion corresponding to a given load, the crank of the fly-wheel should be fixed at the dead point, and steam at a known pressure should be introduced into the cylinder.

435. Torsion Pandynamometer. This instrument is designed to measure the power supplied to an engine or factory, by means of the torsion of the shafting through which the motive power is transmitted. *G. A. Hirn.*

At the extremities of one length of the shafting are keyed two toothed wheels of equal diameter, which gear, one directly and the other by an intermediate wheel, into two smaller pinions. The axes of these pinions govern by their extremities, which are directed towards each other, the four bevelled wheels of an ordinary differential movement. The two intermediate wheels of this movement are loose on a shaft, which is continued in a vertical direction, and made of a light steel rod. The result of this arrangement is, that if the shaft twists, this rod deviates, and forms with a vertical line an angle proportionate to the torsion to which the shaft is subjected. At the upper and loose extremity of the steel rod is secured, by means of a hinge, a horizontal and very light wooden bar, carrying at its extremity a roller, to which is attached a recording apparatus. This roller, when the shaft is at rest, lies in the centre of a wooden disc covered with paper, and revolving uniformly on a vertical axis.

So soon as the steel rod deviates from a vertical line, in consequence of the torsion of the motive shafting, the roller leaves the centre of the disc, and begins to revolve. The turns registered by the recording apparatus are exactly proportional to the torsion of the shafting.

The mean torsion of the shafting being thus known for a day's work, two parallel levers, placed in contrary directions, are securely fixed at the extremities beyond the two toothed wheels, and the loose extremities of the levers, so as to determine the deviation caused in the vertical bar by a given weight.

Simple proportion then gives the weight, corresponding to the mean angle obtained during a day's work, and it becomes easy to determine the mechanical work which corresponds to this angle.

435a. Method of ascertaining **Angles of Torsion** by means of instruments constructed by Professor Wischnegradski.

Laboratory of Mechanics, Technological Institute, St. Petersburg.

This is composed of a support fixed with two horizontal screws in the given section of the beam subjected to the process of torsion. This support upholds an horizontal axle, upon which is fixed an arc, bearing the teeth, whose pitch measures an angle of 2,440 seconds. This arc catches an endless screw, the head of which bears a circle divided into 244 equal parts, and furnished with a fixed decimal vernier; the arc also carries a very sensitive level, placed at the beginning of the experiment in a horizontal position.

The angle of torsion between the two given sections of the beam is calculated by two instruments exactly similar. The deformation of the twisted beam causes an inclination of the levels of both instruments; they are restored to their original position by means of the endless screws, and then is effected the reading of the angles described by the arcs of the two instruments. The difference between these angles is the angle of torsion wanted.

In the Laboratory of Mechanics of the Technological Institute of St. Petersburg the well-known apparatus of Mr. Wöhler is used for the torsion of trees, the photograph of which, taken together with the instruments for measuring the angles of torsion, is exhibited. For demonstrating how to use the instruments, a provisional apparatus is exhibited, wherewith the torsion of the beam is effected by means of a simple lever.

435b. Dynamometer Waggon, for marking and registering the tractive power, and the distances travelled.

Eastern Railway of France Company, Paris.

436. Theoretical Tension-Diagram for calculating the mechanical work in a steam cylinder.

H. Hädicke, Demmin, Pommerania.

X.—MEASUREMENT OF ANGLES.

437. A 10-inch Protractor, by Ramsden. *Royal Society.*

438. Clinometer of Precision, employed in 1865 by Professor Piazzi Smyth inside the Great Pyramid.

Prof. Piazzi Smyth.

This instrument was made to order by J. Cook and Sons, of York, in 1864, at the cost of Andrew Coventry, Esq., of Edinburgh, for measuring the interior slopes of the Great Pyramid. When thus used it was further mounted on a deep wooden beam, 120 inches long, armed with feet of gun metal.

The angle measuring portion of the instrument is a complete circle, provided with three pairs of opposite verniers, each reading to 10″ in order to eliminate errors of division as well as eccentricity, and the whole circle can be moved and clamped on its centre so as to repeat any required angle all round the circumference. On the voyage to Egypt a thermometer broke inside the box, and the mercury tarnished the divided rim in parts. The Pyramid angles were printed in Vol. II. of "Life and Work at the Great Pyramid," by Professor Piazzi Smyth, in 1867.

439. Clinometer of Precision, with improved mounting, readers, and level. *Prof. Piazzi Smyth.*

This instrument was made to order by E. E. Sang, of Edinburgh, in 1869, and intended for measuring Great Pyramid angles of slope. It carries its own footbar, 25 inches long, has improved readers and illuminators, and a chloroform level, as being more quick and frictionless than either ether or alcohol. The circle can be rotated and clamped on its own centre for due repetition of the angles round the circumference ; the verniers read to 1′, and there are supplementary verniers for investigating errors of division.

440-1. Drawings and Photographs of Dividing Machinery. *Messrs. Troughton & Simms.*

Fig. 1. General view of dividing machine.

A. The circular table with racked circumference containing 4,320 teeth, each tooth, therefore, equal to five minutes of arc.

B. The screw by which movement is communicated to Table A.

C. A ratchet wheel attached to the screw shaft.

D. A crank arm which during one half of a revolution gives a forward movement to the screw ; during the remaining part of its revolution the screw is at rest. The axis which carries the crank arm has a bevelled wheel upon it, serving to communicate motion to the cutting apparatus.

E. The cutting frame.

F. A cam to give movement to the dividing knife or other tool by which the division is made.

The apparatus is so arranged that the division may be cut whilst the circular table is at rest, the tool being lifted by a second cam (not well seen in the drawing) when the table is in motion.

Fig. 2. Plan of cutting apparatus showing the relation it bears to the circular table and screw.

Fig. 3. Section of table and axis.

Fig. 4. Drawings of cams and cutting frame, the cam "h" for lifting the tool (just seen in Fig. 1) is here shown.

442. Clinometers, devised by the Rev. Professor Henslow, one of which was used by Dr. Hooker in his Himalayan journeys. *J. D. Hooker, M.D., P.R.S.*

443. Protractor, with scale, vernier, and magnifying glass. Reads to 1 min. *Prof. Baron von Feilitzsch, Greifswald.*

443a. Plate Glass Sector, designed for the purpose of plotting angles on plans or charts where it is necessary to see the work under the sector, and the divisions being on the side next the paper no variation in pricking off can take place.

Thos. F. Chapp.

443b. Instrument for the Measurement of Angles.
Dr. Fr. Holler, Selbo Drontheim, Norway.

XI.—MEASUREMENT OF TIME.

444. Clock Dial. The hours, six only, are indicated by perforated Roman letters. The hand or pointer is formed of a revolving disc, painted in oil, with the subject of Aurora and the Hours; it must have gone round four times in 24 hours. The dial is fitted in the original carved door of the clock. *Italian.* 17th century. *Rev. J. C. Jackson.*

445. Clock, in the shape of an orb of silver-gilt, covered with silver filigree, suspended from a ring which is surmounted by a cupid. The base of black marble is ornamented with beads enriched with silver-gilt filigree, enamels, and precious stones. *German* (*Hamburg*). Dated 1685.

Rev. J. C. Jackson.

446. Clock, in gilt ormolu case, engraved with figures of soldiers and festoons of flowers and fruit. It has a single hand, and strikes the hours. The present pendulum has been substituted for the old bob. *English.* Early 17th century.

Rev. J. C. Jackson.

447. Two Chronometers, by Arnold. *Royal Society.*

447a. Chronometer, with **Glass Balance Spring.**

E. Dent.

This is the invention and handiwork of the late Frederick Dent, of the Strand and Royal Exchange, and the only specimen in existence. The spring requires far less compensation for any given change of temperature than a steel spring would, and the balance, which is composed of a glass disc, is compensated by the two small compensation laminæ mounted upon it.

448. Chronometer Balance, "cut open" for action of heat and cold; ordinary construction without auxiliary.

James Poole & Co.

449. Chronometer Balance, in rough state from casting.

James Poole & Co.

450. Pocket Chronometer, of silver, for inland observations.

James Poole & Co.

451. English Keyless Mechanism. Models and specimens of workmanship for fuzee and going barrel: $\frac{3}{4}$ plate lever and pocket chronometer movements. *James Poole & Co.*

452. Keyless Watch, complete, with fuzee.

James Poole & Co.

452a. Dipleidoscope with Telescope. *M. Lutz, Paris.*

453. Keyless Watch, complete, with centre seconds and going barrel. *James Poole & Co.*

454. Ship Chronometer (2 day), complete.
James Poole & Co.

455. Ship Chronometer (2 day). Movement reversed, to show workmanship. *James Poole & Co.*

456. Chronometer Movement (2 day), as received from the factories in Lancashire. *James Poole & Co.*

456a. Six Chronometers with rates from the Geneva Observatory, stating records of trials of the years 1875 and 1876.
H. R. Ekegrén, Geneva.

No. 16,175,	gold,	open face,	21 lines,	keyless.
No. 16,873,	„	„	18 „	„
No. 16,144,	„	„	Chronographs, 19 lines,	keyless.
No. 16,534,	„	hunter,	21 lines,	keyless.
No. 16,576,	„	„	19 „	„
No. 16,525,	„	„	18 „	„

457. Regulator Clock, filled with the Exhibitor's new patent gravity escapement, having no upward locking, and which cannot trip or slip teeth. *Alfred John Higham.*

On the escape wheel there are two sets of teeth, one set longer than the other; the teeth of each set are arranged, and the pallets are formed and placed, so that the shorter set of teeth only are used, except in case of accidents, when the longer set come into action. This secondary locking entirely prevents irregularity in the clock rate, but the clock can be allowed to run, if desired to be so set to time, by removing two extra stops which are adjustable. The action of the escapement is ordinarily exactly the same as that of the gravity escapements invented by Mr. Denison (Sir Edmund Beckett, Bart.), and the secondary locking can be applied to those escapements.

458. Regulator, with improved gravity escapement on the Bloxamic principle, as arranged and patented by Mr. Higham; founded on the old pin-wheel escapement, and fitted with a galvanic interruptor for chronographical and other astronomical purposes. *Charles Frodsham & Co.*

459. Marine Chronometer, fitted with a galvanic interruptor for chronographical and other astronomical purposes.
Charles Frodsham & Co.

460. Apparatus for demonstrating the application of the pendulum to the clock, at the same time serving for audibly indicating the minutes.
The Secondary Government School at Assen (Netherlands).

This apparatus is constructed by C. H. Van der Heyden, watchmaker, at Assen (Netherlands), after deliberation with Dr. A. Van Hasselt, teacher at

the school for middle-class education at Assen. Price about 4*l*. The escapement may be pulled forward so as to allow the wheel to turn freely. In this manner it may be demonstrated, that clockwork without a pendulum will acquire an accelerated motion.

The escapement must be kept in a forward position, until the weight has reached the ground.

The apparatus, as it audibly indicates the minutes, may also be used for experiments to demonstrate the laws of the pendulum, the laws of hydrodynamics, &c.

461. New System of Electric Clocks.

Prof. F. Osnaghi, Vienna.

In these electric clocks the uncertainty of the action of the greater number of electric pointers has been avoided by causing the electric stream to flow with almost unabated force, as if there were no other clocks present. This is attained by giving the electro-magnets double coils of very unequal resistance. The spirals with great resistance serve for the attraction of the needle from a distance; the spirals with little resistance for retaining the already attracted needle. With every clock there is also a wire coil for the general return current, through which the electric stream can circulate until the attraction of the needle is complete, when its course is diverted by certain mechanism, and is forced to pass over to the next clock.

462. Model of a Clock with four Faces, to be worked by water. *Major M. L. Taylor, R.A.*

463. Sir W. Congreve's Clock, in which the action of the pendulum is replaced by the motion of a small steel ball on an inclined plane, which it descends in 30 seconds.

Major M. L. Taylor, R.A.

464. Model of a Protomotive Clock.

The Committee, Royal Museum, Peel Park, Salford.

An apparatus consisting of a dial with hour and minute hands, and a gutta-percha tube 100 feet in length, the object of which apparatus is to demonstrate how a number of such dials in distinct situations may be made, by means of a column of air at natural pressure, to indicate the same time as the clock with which they are connected. Invented and made by the late Richard Roberts, C.E., Manchester, about the year 1848.

465. Ley's Compensating Pendulum. *Henry W. Ley.*

An inexpensive pendulum compensation is to be obtained by the employment of zinc and flint glass.

466. Ley's Entirely Detached Gravity Escapement.

Henry W. Ley.

The object of this escapement is to cut off absolutely from the pendulum the clock train with its variations, and thus to make the work of the pendulum constant. The arrangement of the escapement shown in the Figs. permits the motions of the various parts to be clearly followed. The scape wheel has six long teeth A, Figs. 1, 2, 3, and 4, by means of which it is "locked," and six "impulse" pins B near its arbor. The arbor carries a fly, not drawn. The pendulum receives its impulse at each alternate beat; at the beats from

right to left in the Figures. The parts of the escapement are: (1), a pallet C; (2), a lever D, having the same axis as C, and resting normally against a fixed stop, from which it can lift, but below which it cannot fall; (it is in its normal position in Figs. 1, 3, and 4); (3), an arm E, of which one end can turn on a pin in D, and the other end, which is free, is lifted by the impulse pins, and rests on them successively; (it is resting on an impulse pin in Fig. 1); (4), a first detent F, against which C sets when at the top of its lift; (C is thus set against F in Fig. 1); (5), a second detent G; and (6), set on a spring, a stop H, against which the scape wheel locks.

The action of the escapement is as follows:—Suppose (as represented in Fig. 1) the scape wheel to be locked and that C has been lifted from its lowest position through an angle $\alpha + \beta$ to the top of its lift. Suppose also that the pendulum is moving to the right from the end of its swing at the left. First, a slot or a pin in the pendulum rod (a pin is supposed here for simplicity sake, and the path of the pin is shown by the dotted curve in each Fig.) lifts G, idly, which falls back to its normal position, that of Fig. 1, immediately the pin has passed; then the rod itself, towards the end of its swing to the right, impinges against a "beat" pin c in C, and, still rising, carries C with it as far as it goes through a further angle γ. In rising through γ, C takes up D with it, and the free end of E, which was resting on the impulse pin by which it was lifted, is carried clear of that pin (now see Fig. 2), and drops on to B¹, the impulse pin next below, depressing F in its drop, and afterwards holding F down (see E and F in same Fig.). The pendulum now returns, from right to left, and C with D falls back through γ, D being arrested at the fixed stop; the free end of its arm E still resting on B¹, and still holding F down. The pendulum continuing its descent, C falls

Fig. 1.—The pallet against the first detent.

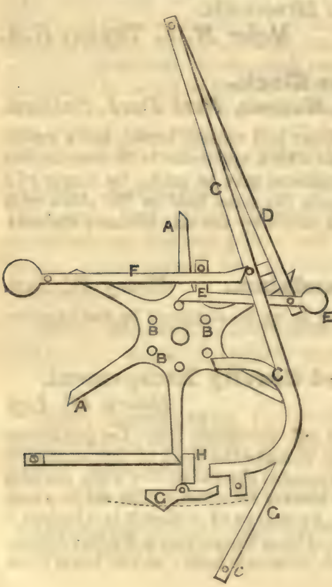


Fig. 2.—At the end of the pendulum swing to the right.

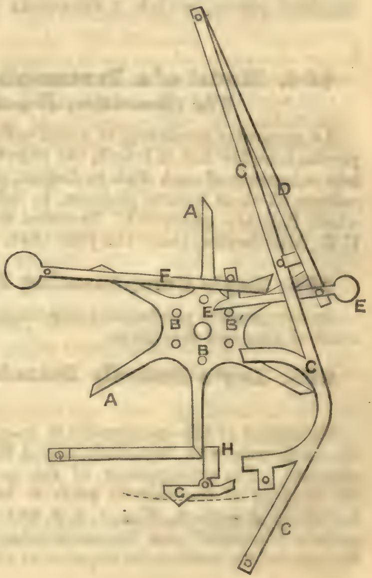


Fig. 3.—The pallet against the second detent.

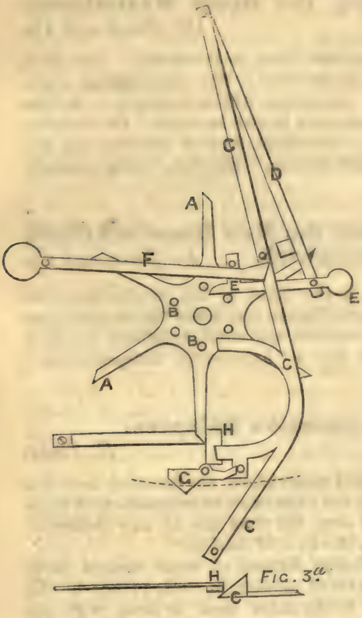
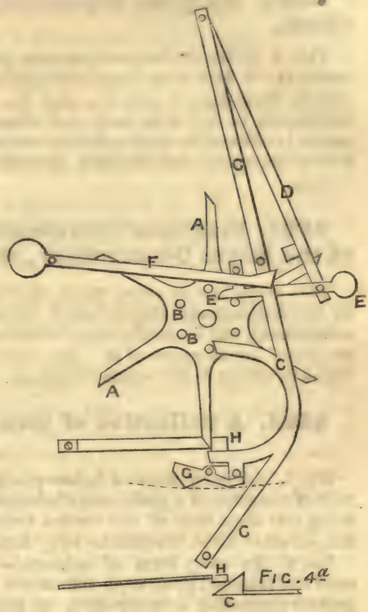


Fig. 4.—The pallet at its lowest position.



back through β, the detent F being out of the way, as far as the detent G (here see Fig. 3), where it stops. In this fall through β, C gives the impulse. The pendulum now moves on by itself, until presently the pin in its rod once more lifts G, not however idly now, but releasing C, which falling back further through α + to its lowest position (shown in Fig. 4), unlocks the scape wheel from H. The position of H with respect to that part of C which acts upon it is shown in plan in Figs 3*a* and 4*a*, in Fig. 3*a* just before, and in Fig. 4*a* just after the unlocking of the scape wheel. The pendulum having lifted G, continues its swing to the extreme left, whence it was supposed started. The scape wheel, free to move, lifts C and also E, the detent F, which is weighted so as to rise of itself, following E's motion, and being in position to hold C when the lifting is done, which is the case just before the next long tooth of the scape wheel coming round and setting against H (which returned to its normal position as C in lifting cleared it), things are again as represented in Fig. 1.

It will be seen from the above description that the pendulum is never in connexion with the clock train, not even for unlocking, and is therefore exposed to no inequality whatever in the work it has to do. The pressure of the scape wheel against the stop by which it is locked varies. This variation, however, is altogether apart from the pendulum, as the unlocking is done by the pallet.

In the arrangement drawn the impulse is not given across the line of centres; it can, however, be so given by appropriate modifications of the various parts.

466a. Jamin's Compensator. *M. Lutz, Paris.*

466b. Diagram representing the Great Westminster Clock. *E. Dent and Co.*

This is by far the largest and most powerful clock in the world. The clock frame is 15 feet 6 in. long, and 4 feet 10 in. wide. The escapement is the double three-legged gravity, and the pendulum which controls it weighs 685 lbs., is 14 feet 5 in. long, and vibrates once in two seconds. Its compensation is effected by zinc and iron tubes. The dials, four in number, are 22½ feet in diameter, and the bell on which it strikes, "Big Ben," weighs nearly 14 tons.

466c. Diagrams representing the New Standard Clock of the Royal Observatory, Greenwich. *E. Dent and Co.*

This clock has an escapement, shown in the front of the picture, invented by the Astronomer Royal, which in some degree resembles the chronometer escapement, but in nearly every other particular the clock exhibited by us is an exact counterpart of it. The clock has a "barometric compensation" which is shown in the second diagram.

466d. A Collection of Compensation Balances. *E. Dent.*

No. 1. An early form of balance.—Steel connexions are fastened near the root of the rims of a plain brass balance; the expansion or contraction of these being less than that of the central brass arm, the rims are by any change of temperature tilted towards or away from the axis of motion.

No. 2. An early form of balance.—Loops formed of brass melted on to steel are fastened upon each side of the axis of motion, in consequence of the greater expansion or contraction of the brass, these open or close with the change of temperature, and drag in or thrust out the small brass weights, to which they are attached by wires.

No. 3. An early form of balance.—The rims are of brass melted upon steel, the brass being outwards; with any change of temperature the rims open or close.

No. 4. An early form of balance.—A flat steel bar has soldered to its extremities underneath pieces of brass; the ends of the steel bar carry uprights bearing weights upon their summits, the brass pieces underneath having a different rate of expansion to the steel, bend it either upwards or downwards, and tilt the uprights carrying the weights towards or away from the axis of motion.

No. 5. A balance of similar design, but having brass melted upon the steel, instead of merely being soldered to its extremities.

No. 6. A balance of modern design, similar in its action to No. 5.

In order to obtain perfect compensation, it is found that for an increase of temperature the compensation weights must advance more rapidly towards the axis of motion, than for the same decrease of temperature they would recede from it. This peculiarity necessitates what is called secondary compensation. The following balances have been introduced to obviate this error:—

No. 7. Compensation pieces formed of brass melted upon steel receive such curves, that with any increase of temperature the compensation weights move towards the axis of motion more directly than they recede from it with any decrease of temperature. (Dent's balance.)

No. 8. A compensation bar is formed, as in No. 5, by brass being melted upon steel, and this bending upwards or downwards, with any change of temperature, tilts the weights carried by the staples towards or away from the axis of motion. But the staples are themselves compensation pieces, and they lift the weights higher with any increase, and depress them with any decrease of temperature, and in this manner increase the rate at which they approach the axis of motion, and diminish the rate at which they recede from it. (Dent's patent balance.)

No. 9. A balance of nearly the same form as No. 6, but the section of its rim is somewhat in the shape of a prism; the form of the rim offers less resistance to the motion of the compensation weight inward than outward. (Dent's registered balance.)

No. 10. A balance similar to No. 5 is mounted upon the arm of a balance similar to No. 6. With any increase of temperature, the first balance can assist the second, but with any decrease of temperature its motion is checked. The whole combination, therefore, is more effective in the heat than in the cold. (Glover's form.)

No. 11. An experimental balance, contrived for the purpose of removing weight from the centre, both with an increase and decrease of temperature. (Wetherill's form.)

No. 12. An auxiliary compensation is added to a balance similar in form to No. 6. The auxiliary consists of two double compensation pieces, and the effect is to carry weight towards the axis of motion, both for an increase and decrease of temperature. The effect of the main compensation weights is therefore increased in the heat and diminished in the cold. (Dent's balance.)

No. 13. A balance of similar design to No. 8, but arranged so that the secondary compensation can be altered with greater facility. (Dent's balance.)

No. 14. A balance having the same general operation as No. 8, but the effect is obtained by straight bars only. The secondary compensation can also be altered without inconveniently disturbing the main compensation, and both without producing any great alteration in the time of the chronometer. (Dent's balance.)

467. Drawings of Compensation Balances, Escapements, and other appliances connected with the construction of Clocks and Watches. *The British Horological Institute.*

Lever Escape Wheel.
Lever Escapement.
Double Roller Lever Escapement.
Two Pin Lever Escapement.
Chronometer Escapement.
Duplex Escapement.
Club Tooth Lever Escapement.
Verge Escapement.
Horizontal Escapement.
Double Roller Lever Escapement with Compensation Balance.
Marine Chronometer Escapement.
Compensation Adjustment by Sir G. B. Airy, Astronomer Royal, 1875.
Double Three-legged Gravity Escapement as used in the Westminster Great Clock.
Dead Beat Clock Escapement.

Pin Wheel Clock Escapement.

Zinc and Steel Compensation Pendulum as used in the Westminster Great Clock.

467a. Compensation Balance arranged in Two Groups.

GROUP I.—Earnshaw's balance with circular rim (1795), and modifications thereof to the present time.

Earnshaw's balance.
Modification of do.
Do. do.
Do. do., with extra adjusting screws.
Do. do., with screws for weights.
Do. do. do. do.
Do. do., with screws for more minute adjustment.
Do. do. do. do. do.
Do. do., with double weights.
Do. do., with variation of weights.
Do. do., with auxiliary by Molyneux.
Do. do., do. do.

GROUP II.—Balances of a form distinct from Earnshaw's, from Hardy (1805) to the present time.

Hardy's balance.
Arnold's do.
Dent's do.
Balance with laminated arm and rim.
Hartney's balance.
Do. do. cup.
Modification of Hartney's balance.
Kullberg's flat rim balance.
Do. double-flat rim balance.
Cole's balance.

The British Horological Institute.

467b. Modification of Molyneux's Auxiliary.

Eiffe's mercurial auxiliary.
Poole's auxiliary.
Example of recent auxiliary.
Do. do. do.
Do. do. do.
Compensation adjustments by the Astronomer Royal (Sir G. B. Airy).

The British Horological Institute.

468. Enlarged Model of Compensation Watch Balance.

The British Horological Institute.

469. Ordinary Marine Chronometer Compensation Balance. *The British Horological Institute.*

470. Models (twelve) **of Compensation Balances,** showing various attempts to overcome what is known as the "Error" of the ordinary Compensation Balance.
The British Horological Institute.

471. Models (ten) **of Compensation Balances,** showing various attempts to overcome what is known as the "Error" of the ordinary Compensation Balance, by the late Thomas Hewitt.
The British Horological Institute.

472. Marine Chronometer by Earnshaw.
The British Horological Institute.

473. Marine Chronometer with Midge's Escapement.
The British Horological Institute.

474. Grossmann's Micrometer.
The British Horological Institute.

475. Model of "Ferguson's Paradox."
The British Horological Institute.

476. Model of Cole's Resilient Escapement.
The British Horological Institute.

477. Callipering Engine, by the late Richard Roberts.
The British Horological Institute.

478. Models of English and French Repeating Motions for Watches. *The British Horological Institute.*

479. Watch Movement.
The British Horological Institute.

480. Marine Chronometer Movement.
The British Horological Institute.

481. Collection of Watch and Chronometer Balance Springs. *The British Horological Institute.*

482. Map showing allowance of time to be made for velocity of sound as applied to the **Westminster Clock Bell.**
The British Horological Institute.

483. Universal Dial, made in 1616 for Prince Charles.
The Royal United Service Institution.

Presented to the United Service Museum, in 1832, by Captain W. H. Smyth, R.N., K.F.M., F.R.S., &c., &c.

484. Timekeeper, which was twice carried out by **Captain Cook.** *The Royal United Service Institution.*

This timekeeper is thus spoken of in Cook's Voyage to the Pacific, 1776, Vol. I., p. 4 : "I had likewise in my possession the same watch or time-"keeper which I had in my last voyage, and which had performed its part "so well. It was a copy of Mr. Harrison's, constructed by Mr. Kendall."

This watch was taken out again by Captain Bligh, 1787, and when the crew of the "Bounty" mutinied it was carried by the mutineers to Pitcairn's Island. In 1808 it was sold by Adams to an American, Mr. Mayo Fletcher, who sold it in Chili, and in 1840 it was purchased for fifty guineas by Sir Thomas Herbert. It was repaired and rated at Valparaiso, and taken by Sir Thomas to China, and brought home in the "Blenheim" in 1843, having kept a fair rate with the other chronometers for the space of three years.

Presented to the institution by Admiral Sir Thomas Herbert, K.C.B.

485. Universal Dial, in use about 160 years ago.
The Royal United Service Institution.

Presented to the United Service Museum in 1838, by His Royal Highness the Duke of Sussex.

486. Month Equation Clock, with double pendulum and dead-beat escapement by Quire, showing minutes and seconds both sidereal and mean time, also sun fast or slow, and containing an annual almanack, mentioned in Cooke & Maule's account of Greenwich Hospital in 1789. *Royal Naval Museum, Greenwich.*

487. Pendulum Clock for marking the time according to the time system of nature.
Hans Baumgartner, Basle, Switzerland.

The pendulum has the exact length of a longitudinal unit of natural measure, that is to say, of the one hundred thousandth part of a degree, of which 540 go to a meridian, and measure the natural second, or the one hundred thousandth part of a mean day.

487a. Pendulum. *Professor Dr. A. Kreuzer.*

A barometer tube of about 350^{mm} length is attached to the pendulum rod in the plane of swinging; a little quantity of dry air is introduced in the upper part of the tube: height of the mercury column about 150^{mm}. The rising and falling of the mercury, depending on the variations of atmospherical pressure, will affect the length of the pendulum, viz., the clock-rate. It will be very easy to calculate the distance from centrum, at which the tube is to be attached; then the barometrical variation in the clock-rate will be compensated. A pendulum of this construction has been used with success at the Etchingforr Observatory since 1866. *See* for theory: Astronomische Nachrichten, Vol. 62, No. 1482.

488. Clepshydral Escapement.
W. H. Miller, M.A., F.R.S.

By means of the fountain bottle of Berzelius, or Gay-Lussac's syphon washing bottle, or any similar contrivance, a current of water is directed into a capsule, from which it is transferred by a syphon to the mouth of an inverted syphon partly filled with fine sand, one leg being rather more than twice as long as the other. The upper end of the short leg is stopped with a cork, in which is inserted a short syphon about 0·29 inch (8^{mm}) in diameter. A compensated pendulum carrying near its upper end at a distance of 5·5

inches (140^{mm}) an inverted funnel about 0·63 inches (16^{mm}) long, 0·27 inches (7^{mm}) wide at its base, and about 0·04 inches (1^{mm}) at the upper end. The lower end of the upper syphon is supported at about 0·12 inch (3^{mm}) above the top of the funnel carried by the pendulum when at rest. A tube of about 0·08 inches (2^{mm}) in diameter, and 0·4 inches (10^{mm}) long, is supported with its upper end about 0·12 inches (3^{mm}) below the lower end of the funnel at rest.

The pendulum being made to vibrate through a small arc before reaching the upper syphon takes up a drop, and on arriving near its lowest point delivers a drop to be carried off. The time is thus measured without allowing the pendulum to come in contact with any solid body except the agate plane on which it is supported.

The drop given off by the lower tube at the end of every two seconds, may be used to record every second second of time by means of a timepiece having a very light pendulum timed in accordance with the pendulum of the water clock.

The figure exhibits the action of the water on the pendulum. No attempt has been made to exhibit the counting of the seconds.

488a. Model of Compensation Balance, applicable to watches and chronometers. (With a drawing.)

M. Winnerel, Paris.

488b. Model of Escapement, applicable to the model clock at the Paris Observatory. (With a drawing.)

M. Winnerel, Paris.

488c. Model of Escapement, with simplified suspension, applicable to clocks. (With a drawing.)

M. Winnerel, Paris.

488d. Drawings of a Simple Counter, and of a Registering Counter.

(*See* Report of Baron Séguier to the Society of Encouragement, 1844.) *M. Winnerel Paris.*

489. Standing Pendulum Clock, in black wooden box with silvered dial. *Professor Buys-Ballot, Utrecht.*

It is one of the first clocks made after Huygen's principle (*i.e.*, provided with cycloidal pendulum). This peculiarity may be seen by opening the door.

490. Two Conical Pendulum Clocks, for determining short time intervals. *Professor Buys-Ballot, Utrecht.*

Each of these clocks is contained in a topped-off wooden column covered by a circular brass plate, by lifting which you see the dial. The foremost part of the box can be removed to put the pendulum in motion, the spring being wound up. In this condition only one hand moves. By pressing on the button at the foremost part of the dial, the two other hands move until you withdraw your finger. In this manner very short lapses of time can be measured. The instruments must be placed accurately horizontal. These two specimens were used by Molland van Beek on the heath near Amersfoort for determining the velocity of sound. They are constructed for the decimal division of time, and indicate the ten millionth part of a day (24 hours).

491. Ancient Striking Clock.
Lent from the Patent Office Museum by the Commissioners of Patents.

This clock is of Swiss manufacture, and supposed to have been made in the year 1348. It was obtained from Dover Castle, and had never been removed from there till the year 1872. It is interesting from the fact of its having the verge escapement, which was used many years before the pendulum.

491a. Very curious Timepiece, apparently designed by Mudge. *E. Dent.*

The escapement is a true remoutoire; two small pendulum springs are wound up at every beat of the scape wheel, and these give impulse to the balance. The balance is controlled by two pendulum springs, one above and the other beneath it; the first of these receives the action of the "compen-" sation curb," the second is for ordinary regulation. The action of the "compensation curb" is analogous to the ordinary regulation by curb pins, but the curb pins are advanced backwards or forwards along the spring by the operation of the compensation pieces, which, being constructed of brass melted upon steel, bend at every change of temperature. The whole timepiece has been designed and got up with a surprising degree of refinement.

492. Working Model of Chronometer Escapement, with two inch scape wheel. *Philip John Butler.*

493. A Small Electric Pendulum. Striking seconds on a bell, and thus capable of being used for astronomical studies. *Antoine Joseph Gérard, Liége.*

494. Book containing plans of instruments, apparatus, and machines. *Antoine Joseph Gérard, Liége.*

499a. Chronometrical Regulator, for putting in motion a registering cylinder. *Mr. Yvon Villarceau.*

This system of regulator, the theory of which is due to Mr. Yvon Villarceau, is represented by the model included among the objects exhibited by M. L. Breguet.

500. Edelmann's Seconds Pendulum, with galvanic attachment. *M. Th. Edelmann, Munich.*

501. Chronometric Comparateur, an instrument of coincidences, for determining the difference of time between two distant clocks. *M. Redier.*

501a. Collection of Steel and Electro-gilded Pendulum Springs. *E. Dent.*

502. Clock employed in the Pantheon Experiment by M. L. Foucault. *Conservatoire des Arts et Méiters, Paris.*

502a. Different applications of Metal Tubes of ellipsoidal section to instruments for measuring pressure, temperature, weight, speed, and time.

1. Manometer for steam, air, or water pressure.
2. Barometer. Counterpoised barometer.
3. Thermometer.
4. Tacheometer, or speed indicator.
5. Balance for light and heavy weights.
6. Clock with pneumatic motor.

M. Eugene Bourdon, Paris.

503. Electric Apparatus by M. Foucault, for keeping up continuously the motion of the clock.
Conservatoire des Arts et Métiers, Paris.

509. Marine Chronometer, regulated at sidereal time, used by the Scientific Commission of Noumea in observing the passage of Venus. *Messrs. Tondola and Co., Paris.*

510. Marine Chronometer, suitable for distributing the hour in quarter minutes to an unlimited number of electric receptors, going for one year without being wound up. (System applied for more than three years with complete success.)
Messrs. Tondola and Co., Paris.

511. Marine Chronometer, regulated to mean time. Specimen of ordinary construction. *Messrs. Tondola and Co., Paris.*

512. Geographical Clock, with revolving planisphere; showing the time, longitude, and latitude, of all parts of the globe.
Messrs. Tondola and Co., Paris.

513. Astronomical Pendulum Clock.
W. Bröcking, Hamburg.

514. Wheel-work of Clock. *W. Bröcking, Hamburg.*

515. Astronomical Pendulum Clock with mercury compensation pendulum. *Th. Knoblich, Hamburg.*

516. Sympathetic Pendulum. *Th. Knoblich, Hamburg.*

517. Chronometer-escapement, model.
Th. Knoblich, Hamburg.

518. Anchor-escapement, model.
Th. Knoblich, Hamburg.

519. Pendulum Clock belonging to the tide-gauge of Mr. Reitz. *Th. Knoblich, Hamburg.*

520. Astronomical Pendulum Clock.
F. Dencker, Hamburg.

The compensation pendulum system Jürgens has an isochronous suspension spring, determined by calculation. It is, contrary to the formerly con-

structed repose pendulum, executed with sufficient stability. Not only is the expansion coefficient of the separate bars exactly determined in the pyrometer, but likewise the whole pendulum is directly controlled, as regards length and extension, in the pyrometer. The pyrometer employed is of quite a novel construction; the observation takes place in a liquid, *without contact*, under two micrometer microscopes. Accuracy: 1 scale division $= \frac{1}{1200}$ millimeters. As the observation through the microscope requires perfectly clear water, the uniformity of its temperature is ensured; the bars likewise must be quite homogeneous, as otherwise a bending of them will take place by a change of the temperature, whereby the terminal ends will move out of the range of vision. With regard to compound pendulums, the centre of gravity is to be found by means of a balance the point of flexion of the spring of which is known to the exhibitor; in a quite homogeneous and uniformly strong balance it is exactly in the centre. By means of a bar the centre of gravity is indicated on the length of the pendulum,* and the whole pendulum is controlled in the pyrometer as to temperature and stability.

521. Model Escapement. *F. Dencker, Hamburg.*

An anchor escapement, enlarged tenfold, with an impulse derived from the chronometer and acting like the same from fork upon balance. The same moves likewise without oil. The straight lines of the fork and the release stone render a quite exact execution possible, and consequently an effect which almost equals the direct impulse from wheel upon balance, without detracting from the great insensibility of the anchor escapement. Arranged for quarter seconds, it will be very useful for determining the time on journeys and on sea. The last seconds are regulated by a curb, permitting only little motion, but being securely guided by means of a screw. The last regulation by the screws always disturbs the equilibrium of the balance, and effects thereby a doubling of the errors at the change of the position. The flat spiral spring has an inner and an external curve.

522. Gold Watch. *F. Dencker, Hamburg.*

The pocket watch has been exactly executed according to this model in the exhibitor's establishment at Geneva. It is provided with a flat spiral spring hardened in fire according to his invention. Up to the present time no flat spiral springs are ever hardened in fire.

523. Watch with spindle without spiral spring; constructed in the East in the first half of last century, indicating month, day, and hour in Arabic figures. (Remarkable for its age and origin.) Property of H.H. Prince Pless, Fürstenstein.

Committee of Breslau.

523a. Watch, thickness of a crown piece, made for the late Sir C. Wheatstone by Mr. A. Stroh.

* The extension of the parts to be employed being known, a pendulum can be determined by calculations which swings in exactly one second.

SECTION 4.—KINEMATICS, STATICS, AND DYNAMICS.

West Gallery, Ground Floor, Room K.

I. SPECIAL COLLECTIONS.

Collection of Apparatus used by 'sGravesande to illustrate his Physical Researches.

524. 'sGravesande's Apparatus to demonstrate the **Laws of Centrifugal Force.**
Professor Dr. P. L. Rijke, Leyden.

(*See* 'sGravesande's "Physices Elementa Mathematica," 3rd edition, Vol. I., p. 153.)

525. 'sGravesande's Apparatus to demonstrate the **Theory** of the **Wedge.** *Professor Dr. P. L. Rijke, Leyden.*

526. 'sGravesande's Apparatus, to show, by means of a pendulum furnished with weights and springs, that the same quantity of **Mechanical Labour** produces the same quantity of **Living Force.** *Professor Dr. P. L. Rijke, Leyden.*

527. 'sGravesande's Apparatus to demonstrate the **Laws** of **Falling Bodies.** *Professor Dr. P. L. Rijke, Leyden.*

528. 'sGravesande's Apparatus for **Parabolic Motion.**
Professor Dr. P. L. Rijke, Leyden.

Collection of Kinematic Models, exhibited by the Königl. Gewerbe-Akademie, Berlin, Prof. Reuleaux, Director.

The models in this collection are connected throughout with Professor Reuleaux's treatment of the theory of machines. Their nature will be found fully discussed in his "*Theoretische Kinematik*" (Vieweg und Sohn). The English edition of this work (Macmillan), translated and edited by Professor Alexander B. W. Kennedy, C.E., of University College, London, will, it is hoped, be ready early in May. The English names of the mechanisms here given are those used by Professor Kennedy in his translation.

551. I.—Pairs of Kinematic Elements.

(*a.*) LOWER PAIRS.

1. Turning or cylinder pair.
2. Sliding or prism pair.
3. Twisting or screw pair.

552. Pairs of Kinematic Elements.

(*b.*) HIGHER PAIRS.

4. Equilateral duangle in equil. triangle.

   These models of the higher pairs of elements can be inverted; that is, the movable element can be fixed, and the fixed element made movable. The centroids are shown in thick black or red lines; the roulettes, or point-paths, in thinner lines.

5. Expanded duangle in equil. triangle.
6. Equilateral curve-triangle in square.
7. Equilateral curve-triangle in rhombus.
8. Expanded isosceles curve-triangle (90°) in square.
9. Expanded equilateral curve-triangle (90°) in rhombus.
10. Regular curve-pentagon in square.
11. Symmetrical curve-pentagon in square.

553. II.—Conic Axoids, with corresponding Spheric Roulettes and Profiles.

12. Spheric epicycloid.

    Ratio 1:3.

13. Spheric cycloid.

    A full cone rolling upon a plane cone (1:3).

14. Spheric hypocycloid.

    A full cone rolling in an open one (2:1).

15. Spheric hypocycloid.

    Ratio 1:3.

16. Spheric pericycloid.

    The curve upon the rolling cone passes always through the describing point of the fixed one.

17. Spheric involute.

    Ratio 1:3.

18. Spheric involute.

    Ratio 8:9; the curve in red is a curtate involute.

19. Apparatus for describing spheric cycloids.

    Describes, among other curves, those here exhibited.

554. III.—Simple Kinematic Chains and Mechanisms.

20. Quadric cylindric-crank chain.
21. Slider-crank chain.
22. Quadric conic-crank chain.
23. Reduced slider-crank chain.
    The link *c* omitted.
24. Reduced slider-crank chain.
    Links *a* and *c* omitted.
25. Reduced conic-crank chain.
    The link *c* omitted.
26. Quadric crank chain with slot and sector.
27. Single crossed slide chain.
28. Double crossed slide chain.
29. Simple spur-wheel chain.
30. Simple spur-wheel chain with annular wheel.
31. Endless screw.
32. Stand for carrying the above models when in use.

555. IV.—Crank Trains.

33. Double slider-crank.
34. Slider-crank.
    With centroids.
35. Slider-crank.
    With centroids.
36. Double slider-crank.
    With centroids. (The centroids are here Cardan's circles.)
37. Slider-crank.
38. Skew double slider-crank.
39. Double slider-crank with curved slide.
40. Double slider-crank with skew slide.
41. Lever-crank.
42. Double slider-crank with curved slide.
    With pin expansion.
43. Slider-crank.
    Link *b* is here a disc.
44. Slider-crank.
    With adjustable connecting rod.
45. Slider-crank.
    With adjustable cross-head.
46. Slider-crank.
    In the form of a marine engine.
47. Slider-crank.
    Slotted link gear.
48. Slider-crank.
    Double slide gear.

49. Slider-crank (Norman Wheeler).
    Three-fold.

50. Slider-crank, with pin expansion, 2 within 1.
51. Slider-crank, with pin expansion, 1 within 2.
52. Slider-crank, with pin expansion, 3 within 2.
53. Slider-crank, with pin expansion, 2 within 3.
54. Slider-crank, with pin expansion, 2 within 3.
    Annular expansion.

55. Slider-crank, with pin expansion, 1 within 2 within 3.
56. Slider-crank, with pin expansion, 3 within 2 within 1.
57. Slider-crank, with pin expansion.
    Adjustable stroke.

58. Swinging block (slider-crank).
59. Turning block (slider-crank).
60. Skew (turning) cross block.
61. Turning block (slider-crank).
    With pin expansion (can be used also as a turning slider-crank).

62. Turning block (slider-crank).
    With reduced centroids.

63. Double crank (drag-link coupling).
    With reduced centroids.

64. Turning block (slider-crank), Redtenbacher's "Maskirte Kurbelschleife."
    Quick return motion; the stroke is adjustable.

65. Swinging slider-crank.
65*a*. Swinging double slider.
66. Swinging skew double slider.
67. Conic crank-train.
68. Isosceles double-crank (Galloway).
    Mean velocity, ratio 1 : 2.

69. Isosceles double-crank (Galloway).
    Mean velocity, ratio 1 : 2; arrangement for crossing dead points, by Reuleaux.

70. Anti-parallel cranks (Reuleaux).
    Special arrangement for crossing dead points.

71. Anti-parallel cranks (Reuleaux).
    With centroids, which are ellipses.

72. Anti-parallel cranks (Reuleaux).
    With centroids, which are ellipses and hyperbolæ.

73. Double parallel crank train, used as a coupling.
    For transmitting uniform rotation.

74. Double parallel crank train, used as a coupling (Reuleaux).
    For transmitting uniform rotation.

75. Crank train for transmitting uniform rotation (Heilmann).
76. Crank train for transmitting uniform rotation (Böhm).

77. Differential crank train (Römer).
Numbers of teeth, 56 and 56, with apparatus for tracing diagrams.

78. Differential crank train (Römer).
Numbers of teeth, 56 and 57, with apparatus for tracing diagrams.

79. Differential crank train (Römer).
Numbers of teeth, 30 and 90, with apparatus for tracing diagrams.

80. Hooke's joint.
81. Universal joint (Blees).
82. Universal joint (Polhem).
83. Universal joint (Reuleaux).
84. Universal joint (Klein).
85. Universal joint (Klein).
Simplified by Reuleaux.

86. Double Hooke's joint.
The velocity ratio here can be made constant.

556. IV*a*.—Mechanisms for describing Straight Lines (exactly or approximately).

87. Roberts triangle, " parallel motion."
88. Triangle motion, inverted, by Reuleaux.
89. Elliptic linkwork (Nehrlich), 3rd form, inverted.
90. Elliptic linkwork (Nehrlich), 3rd form, inverted.
91. Hypocycloidal linkwork.
92. Hypocycloidal linkwork, inverted, by Reuleaux.
93. Epicycloidal linkwork, Reuleaux.
94. Elliptic linkwork, inverted.
With the whole motion.

95. Tchebischeff's linkwork.
Arranged so that it can be inverted.

96. Conchoidal linkwork, 1st form.
97. Conchoidal linkwork, 3rd form (Reichenbach).
98. Conchoidal linkwork, 3rd form (Reuleaux).
99. Lemniscoidal linkwork, 1st form (Watt).
100. Lemniscoidal linkwork, 2nd and 3rd forms.
101. Lemniscoidal linkwork, 1st form, inverted (Reuleaux).
102. Lemniscoidal linkwork, 2nd and 3rd forms.
Steam engine model with Watt's planet wheels.

103. Sector mechanism (Reuleaux).
Involute.

104. Sector mechanism (Reuleaux).
Cycloid.

105. Sector mechanism (Reuleaux).
Cycloid.

106. Cartwright's mechanism.
107. Maudsley's mechanism.
108. Tchebischeff's mechanism.

109. Harvey's mechanism.
110. Harvey's mechanism.
111. Pantograph.
With elliptic linkwork, 1st form.
112. Pantograph.
With prism guide.
113. Semi-pantograph.
With prism guide.
114. Semi-pantograph.
Steam engine model.
115. Rhombic linkwork.

557. V.—Apparatus for describing Curves.

116. Ellipsograph.
117. Ellipsograph, by Slaby, on Haman and Hempel's system.
Describes also cycloids. Dr. Slaby's construction contains very essential improvements.
118. Elliptic chuck (Leonardo da Vinci).
119. Elliptic chuck (Delnest).
120. Sinoid and cardioid tracing gear.
121. Curve tracing apparatus.
122. Curve tracing apparatus.
123. Mechanism for describing Lissajous' figures.
Describes also ellipses.
124. Hastie's conoid gear.
125. Tricentric gear.
For the construction of three-grooved taps, &c.
126. (Form-) copying machine.
127. Rose-engine.
128. Rose-engine.
129. Rose-engine.
130. Rose-engine, special form.

558. VI.—Parallel or Translating Trains.

131. Parallel ruler.
Single and double.
132. Parallel ruler.
With crossed bars.
133. Complete lever parallel train.
Weighing machine, of Roberval.
134. Incomplete lever parallel train.
Weighing machine, of Milward.
135. Incomplete lever parallel train.
Weighing machine, of Farcot.
136. Incomplete lever parallel train.
Weighing machine, of Schwilgué.

559. VII.—Compound Parallel Trains.

137. Feathering paddle-wheel, of Buchanan.
A combination of trains similar to parallel rulers. The floats remain always vertical.

138. Feathering paddle-wheel, of Oldham.
The floats rotate about their axes as the wheel revolves.

139. Feathering paddle-wheel, of Morgan.
With eccentric ring.

560. VIII.—Higher Couplings.

140. Uhlhorn's coupling.
141. Oldham's coupling.
142. Reuleaux's grooved disc coupling.
143. Köchlin's cylindric coupling.
144. Schürmann's cylindric coupling.
145. Conic coupling.
146. Pouyer-Quertier's coupling.

561. IX.—Toothed-wheel Trains.

147. Spur wheels (point-paths used for profiles).
148. Returning spur-wheel train.
149. Returning spur-wheel train, with annular wheel.
150. Returning spur-wheel train, with annular wheel.
151. Returning spur-wheel train, with two annular wheels.
152. Returning spur-wheel train, with two annular wheels.
153. Returning spur-wheel train, with intermediate wheel.
154. Returning spur-wheel train, with intermediate wheel.
Reuleaux's so-called halving spur-wheel train.

155. Returning spur-wheel train.
With Marlborough wheel.

156. Spur-wheel train.
The centroids are Cardan's circles.

157. Beylich's universal wheels.
"Pin-wheels."

158. Cylindric friction wheels.
Held by axial pressure.

159. Screw wheels.
Working as spur-wheels.

160. Screw wheels.
Screw wheel and rack.

161. Bevel wheels.
Plane- (face-) wheel and full wheel.

162. Mangle-wheel train.
Automatic reversal.

163. Mangle-wheel train.
164. Mangle-wheel train.
    With internal teeth.
165. Whitworth's feeding gear for drills.
    The drill is under a constant pressure.
166. Reversing gear, claw coupling.
    With bevel wheels.
167. Reversing gear, bevel wheels.
168. Reversing gear, returning wheel gear.
    By Reuleaux.
169. Reversing gear, Sellers' arrangement.
    Open and crossed belts.
170. Reversing gear, with three pulleys.
171. Face-wheel and runner (Rupp).
172. Speed changing gear (Sellers).
    For lathes.
173. Speed changing gear with double pulleys.
174. Reversing and disengaging train (radial).
    Wheels of 103 and 53 teeth respectively.
175. Reversing and disengaging train (Fairbairn's).
176. Reversing and disengaging train (Brown's).
177. Engaging and disengaging train (Platt's).
178. Engaging and disengaging train (Curtis').

Globoid Gearing.

179. Globoid screw wheels ; spheric screw and wheel.
    Reuleaux.
180. Globoid ring, screw, and wheel.
    Reuleaux.
181. Skew globoid ring, conic screw and tooth.
    Reuleaux.
182. Globoid ring, cone, and wheel.
    Used by Stephenson in locomotive reversing gear.
183. Crossed globoid ring, screw, and tooth.
    Reuleaux.
184. Crossed globoid ring, screw, and tooth.
    Reuleaux.
185. Globoid screw and screw wheel.
    Endless screw.
186. Globoid screw.
    Applied in horse gins; velocity ratio 1:12.

Parallel Wheels.

187. Parallel wheels with 24 teeth.
    Reuleaux. The teeth are revolutes.

188. Parallel wheels with 6 teeth.
Reuleaux. Would work also with 3 teeth. The teeth are pins.

189. Parallel wheels with 5 teeth.
Reuleaux. One wheel annular.

190. Parallel wheels with 24 (pin) teeth.
Reuleaux. The parallelism is destroyed by displacing the axes.

Planet Wheel Chains.

191. Planet wheel chain.

192. Planet wheel chain, $a=b=\infty$.
With excanching wheels.

193. Planet wheel chain, $a=b=\infty$.

194. Planet wheel chain, with annular wheel.

195. Planet wheel chain, $b=c=\infty$.

196. Hyperboloidal endless screw.

562. X.—Belt-trains.

197. Returning belt-train.
Shows the alteration of velocity due to the slipping of the belt.

198. Skew belt-train.
Acts in one direction only.

199. Belt-train with crossed guide pullies.
The necessary tension is given to the belt at the instant it is thrown into gear.

563. XI.—Slider-cam Trains.

200. Sinoidic cams. Cardioids.
Open cam with roller, pair-closure.

201. Sinoidic cams. Cardioids.
With second disc and centroid.

202. Sinoidic cams. Cardioids.
Pair-closure.

203. Sinoidic cams. Polar sinoid.
With centroid.

204. Sinoidic cams. Polar sinoid.
With centroid.

205. Cams with discontinuous profiles. Curve-triangle in skew curved slot.
With centroid.

206. Cams with discontinuous profiles. Equilateral curve-quadrangle.
With centroid.

207. Cams with discontinuous profiles. Equilateral curve-pentagon in straight slot.

208. Cams with discontinuous profiles. Equilateral curve-pentagon in adjustable slot.
Both parts are adjustable.

209. Cams with discontinuous profiles. Curved disc in curved slot.
Both parts are adjustable.

210. Cams with discontinuous profiles. Curved disc.
For the motion of a slide valve.

211. Cams with discontinuous profiles. Disc with looped slot.
With shuttle, used in printing presses.

212. Slider-cam, two-lobed cylindric sinoid.
Force-closure.

213. Slider-cam.
Force-closure.

214. Slider-cam, cylindric sinoid.
215. Screw reversing train of Whitworth.
216. Steering gear of Scott and Sinclair.
217. Steering gear of Steel (Greenock).
218. Steering gear of McWilliam.
219. Steering gear of Reed.
220. Steering gear of Rogers.
221. Steering gear of Reuleaux.
222. Boring machine.
223. Boring machine (Stehelin).
224. Boring machine (Reuleaux).
225. Differential screws.
226. Differential screws, with wheel train.
227. Double screw train (Napier).
Self-acting return.

228. Cam reversing train (Girard).
For governors.

229. Leading screw with disengaging gear.
With self-acting disengagement.

230. Screw disengagement (Whitworth).
With pallet action.

231. Screw heckling machine (Houldsworth).

564. XII.—Ratchet Trains.

232. Click train.
With two external and one internal clicks.

233. Centrifugal click train.
If rapid rotation occur, the centrifugal force throws out the click.

234. Silent click train.
235. Pinching click train.
236. Click train of Wilbers.

237. Ratchet train of Langen.
Used in gas engines.

238. Turning ratchet gear (Maltese cross wheel).
239. Turning ratchet gear (incomplete cross wheel).
240. Turning ratchet gear (spur wheel).
241. Ratchet train.
With automatic disengagement.

242. Ratchet train, with pin teeth.
With automatic disengagement.

243. Ratchet train (Reed).
With automatic disengagement and fall.

244. Ratchet train, with fast click.
245. Single acting ratchet train.
The direction of motion can be altered.

246. Double acting ratchet train.
247. Reversing ratchet train (Francis).
Used for governors.

248. Dividing machine (Nasmyth).
249. Lagarousse ratchet gear.
With eccentric.

250. Crown wheel ratchet train.
251. Tooth ratchet train, with double acting free click.
Model illustrating action of a force pump.

252. Escapement train (Mudge).
Can be held in the stand, No. 32.

253. Throttle click train.
Illustrates the action of the throttle valve.

254. Ratchet train, with pinching clicks.
255. Ratchet train, with several clicks.
256. Ratchet train, with free clicks.
Directing gear can be added so as to illustrate the action of a steam engine.

257. Ratchet train, with fast clicks.
258. Ratchet train, with Farey's director.
259. Ratchet train, with Watt's director.
Watt's automatic valve gear.

260. Double acting ratchet gear.
261. Ratchet train, with cataract director (Hoffmann).
262. Double acting ratchet gear.
(Reuleaux.) Shows that the steam engine is a ratchet train. The model can be worked with various forms of directing gear; it stands upon a large mahogany frame with columns.

263. Apparatus for using with Nos. 244 to 254:—Column with fly wheel and two connecting rods.

Escapements.

264. Graham's anchor escapement.
265. Escapement of Reuleaux.
266. Pin escapement of Lepaute.
267. Escapement of Denison.
With three-toothed escape wheel.
268. Gravity escapement of Denison (1860).
As in the clock at the Houses of Parliament.
269. Gravity escapement of Denison.
270. Spindle escapement.
271. Cylinder escapement.
272. Anchor escapement.
273. Chronometer escapement of Jürgensen.

564a. XIII.—Chamber-crank Gears and Chamber-wheel Trains.

274. Chamber-crank gear, Simpson and Shipton.
Steam engine.
275. Chamber-crank gear, Bährens, Napier, Bompard.
Steam engine.
276. Chamber-crank gear, Wedding, Cochrane.
Ventilator.
277. Chamber-crank gear, Ramelli.
Pump.
278. Chamber-crank gear, Beale.
Gas exhauster.
279. Chamber-crank gear, Cochrane.
Steam engine.
280. Chamber-crank gear, Pattinson.
Pump.
281. Chamber-crank gear, Minari, Stocker.
Steam engine and pump.
282. Chamber-crank gear, Ramey.
Steam engine and pump, with elliptic wheels.
283. Chamber-crank gear, Lemielle.
Ventilator.
284. Chamber-crank gear, Cochrane.
Steam engine.
285. Conic crank gear, Davies.
Steam engine.
286. Parallel crank gear, Galloway.
Steam engine.
287. Chamber-wheel train, Pappenheim.
Pump.
288. Chamber-wheel train, Fabry.
Ventilator for mines.

289. Chamber-wheel train, Fabry.
290. Chamber-wheel train, Root.
Blower.
291. Chamber-wheel train, Root.
Blower.
292. Chamber-wheel train, Payton.
Water-meter.
293. Chamber-wheel train, Evrard.
Pump.
294. Chamber-wheel train, Repsold, Lecocq.
Pump.
295. Chamber-wheel train, Dart, Behrens.
Pump.
296. Chamber-wheel train, Ganahl, Eve.
297. Chamber-wheel train, with three wheels.
298. Screw-wheel chamber train, Révillion.
Ventilator.

II. ELEMENTARY ILLUSTRATIONS.

528a. Parallelogram of Forces.
Dr. G. Krebs, Frankfort-on-the-Maine.

528b. Inclined Plane.
Dr. G. Krebs, Frankfort-on-the-Maine.

528c. Inclined Plane, constructed by Professor Dr. Bertram, Councillor of the Board of Education. *Ferdinand Ernecke, Berlin.*

The inclined plane is represented by two parallel iron rods, which can be placed at any angle desirable to the horizontal bar.

Three tracts (distances) can be measured on the same :—

1. The length of the inclined plane, that is to say, the distance from the turning point (centre of motion) to the perpendicular iron support bar, which maintains the plane in its proper position.

2. The base, that is to say, the horizontal distance from the centre of motion to the support bar; the same is read on the horizontal pedestal.

3. The height, that is to say, the plumb line from the terminal point of the first distance to a horizontal line laid through the centre of motion; this is read on the support bar, the zero point of which is situated on a level with the centre of motion.

The burden on the inclined plane can be arrested in two different ways: either by a motion parallel to the inclined plane, or by a horizontal motion. The carriage of the roller can be turned, and the pulling string can, therefore, be placed parallel to the inclined planes or horizontally. The double division on the slitted support bar serves for observing the horizontal position of the string.

At every experiment the burden carriage, that is, the two-wheeled axle with its scale, is balanced with the scale which is suspended on the string. This is effected by tare weights. Then the burden and the power of traction is adjusted by means of the measured distances, that is to say, the weights which are balancing each other in the burden scale and the traction scale.

1. If the string of the inclined plane runs parallel, then the burden is

proportioned to the traction as the length of the inclined plane is to the height.

For example, if the length be 80 and the height 40, then 20 grammes in the burden scale will be balanced by 10 grammes in the traction scale.

2. If the string runs horizontal, then the burden is proportioned to the traction as the base of the inclined plane to the height.

For example, if the basis be 40 and the height 40, then 4 grammes in the burden scale will be balanced by 20 grammes in the traction scale.

In order to make the difference in the two cases intelligible, such positions in the inclined plane are advantageous in which the three distances are indicated by round figures, such as height, 20; length, 29; base, 21. The weight 20 in the traction scale balances then with the string in horizontal position, the weight 21; and with the string parallel the weight 29 will be equipoised. With the height 30 and the base 40 the length will be 50, and 30 grammes in the traction scale will balance 50 grammes in the burden scale with parallel motion, whilst the burden at a horizontal motion will amount to only 40 grammes.

528d. Parallelogram of Forces, constructed by Professor Dr. Bertram. *Ferdinand Ernecke, Berlin.*

Apparatus for demonstrating the theorem of the parallelogram of forces.

If two adjacent sides of a parallelogram represent in magnitude and direction two forces acting at a point, the diagonal through the point will represent their resultant in magnitude and direction.

This theorem is illustrated by the apparatus. The angular point of the parallelogram is the (white) peg, over which a ring has been placed, on which are fastened the three cords; the magnitude of the forces is determined by the weight in the scales, the direction passes along the three rails, of which the one, AB, which is stationary, vertically upright; the second AC, and likewise the third, AE, movable around the peg A, always moves in the elongated diagonal of the parallelogram BADF. The greatest of the forces is always taken in the direction of AB, and determined as equal to 100, and those of the two others is read on the graduations of the lines BG and AF.

If, for example, the parallelogram is placed so that the lines AB are equal to 100, BF = 70, AF = 80, the ring in that case will poise freely without coming into contact with the peg, if the weights in the scales amount respectively to 100, 70, 80 grammes; of course must the equilibrium of the scale weights be adjusted previously by tare weight.

528e. Centrifugal Apparatus, complete.
Ferdinand Ernecke, Berlin.

529. Drawing. Experimental demonstration of the theory of the parallelogram of forces or velocities, used by the exhibitor since 1835. *Professor Daniel Colladon, Geneva.*

Two small pulleys are placed at some distance from each other on the edge of a table. On the opposite edge, held by the hand, is a small ball of the size of a musket ball, to which are attached, by one of their extremities, two helicoidal springs of fine brass wire; the other extremity of these two springs is drawn parallel to the plane of the table by cords passing over the pulleys, and themselves stretched by the weights P and P′. The table being sprinkled with lycopodium, two lines are traced upon it, marking in direction and intensity the tensions of the two springs which draw the ball, which are equal to the weights P and P′. On discharging the ball it traces on the table a straight line, which is in the direction of the diagonal of the parallelogram of the forces P and P′ of the two springs.

III. PRINCIPLES OF MECHANISM.

529a. Models (13) of the various **Linkworks** for effecting the exact rectilinear motion of a point, commonly known as "parallel motions." *A. B. Kempe, B.A.*

Described by the contributor in a paper published in the "Proceedings of the Royal Society," No. 163, 1875, and entitled, "On a General Method of "producing exact Rectilinear Motion by Linkwork," which points out the common principle on which the linkworks depend. The linkwork No. [8] was discovered by M. Peaucellier in 1864, and No. [13] by Mr. Hart in 1874; the rest were discovered subsequently by the contributor.

The lengths of the links will be found marked on them, and the points which have rectilinear motion are denoted by stars.

529b. The Sylvester-Kempe Parallel-Motion. Model of a linkwork for effecting the exact rectilinear motion of a point. *A. B. Kempe, B.A.*

Discovered simultaneously by Professor Sylvester and the contributor in 1875. The main portion of the apparatus consists of a linkwork of four bent rods called a "Quadruplane," which is such that four points, one on each rod, always lie at the angles of a parallelogram of constant area and angles. Two of the points consequently are situate at such distances from a third that the one distance is the inverse of the other. One of the points being fixed, another is made by means of a link to move in a circle passing through the fixed point, the other then describes a straight line. If the bent rods are made straight, the four points lie in a straight line, and the parallel motion becomes that of Mr. Hart, No. [13].

529c. Model of a Linkwork, by which two rods may be made to rotate about different parallel axles with equal velocities in contrary directions. *A. B. Kempe, B.A.*

This and the four following linkworks are described by the contributor in the "Messenger of Mathematics," No. 44, 1874.

529d. Model of a Linkwork, by which two rods may be made to rotate about the same axle with equal velocities in contrary directions. *A. B. Kempe, B.A.*

529e. Model of a Linkwork, by which rods may be made to rotate about the same axis with velocities proportional to 1, 2, 3, &c. The linkwork can also be used to divide angles into a number of equal parts. *A. B. Kempe, B.A.*

529f. Model of a Linkwork, by which two rods, otherwise free, may be made to remain always in the same straight line with each other. *A. B. Kempe, B.A.*

529g. Model of a Parallel Ruler. *A. B. Kempe, B.A.*

529h. Model of a Parallel Ruler. *A. B. Kempe, B.A.*

529i. Link Motion. *William Howe, Chesterfield.*

The sketch was made by W. Howe, in August 1842, which was the first sketch of the shifting link motion. The small rough wooden model was begun by William Howe, in or about 1838, at the Vulcan Foundry, near Warrington, Lancashire, where the sectional cylinder, piston, valve, and foundation frame were made, but this was not for the purpose of applying the link motion, but a tappet motion. When the sketch referred to above was made, the link motion was applied to that model, and all the parts of the old model that could be brought in were used. The model of the twin bar link was designed, in 1848, by William Howe and Mr. William Usher, who was on a visit to William Howe at the time he made the model.

76c. Instrument, with joint, which makes its upper part moveable in a horizontal plane.

Professor Tchebichef, University of St. Petersburg.

76d. Model of joint, which directly transforms a reciprocating into a circular motion.

Professor Tchebichef, University of St. Petersburg.

530. Drawing and Model of a connecting motion between two shafts turning in reversed ways. *Charles Bourdon.*

530a. Four Models, for the description of tooth-profiles, and lines of contact.

Royal Rhenish Westphalian Polytechnic School at Aix-la-Chapelle.

Model No. 1 illustrates the construction of *general* toothing, according to Reuleaux's method.

Model No. 2 shows that by the describing point of a string which runs over two rollers, two evolvents constantly coming in contact are marked relatively to them, which for this reason are tooth-profiles correctly working together.

As the same profiles are described when the axes are distanced from or brought nearer to each other, it follows that evolvert-wheels may alter the distance of their axis notwithstanding the correct contact.

The top circles " K " and " K_1" cut off from the " *contact line* " *a b*, the *contact space* PP.

Model No. 3 shows that at the *cycloid toothing*, the " *contact space* " consists of the curves (segments) cut off from the head circles, and that every normal placed on the tooth-profile in the common point of contact of two teeth always passes through the point of contact of the two dividing circles.

Model No. 4 evolves spontaneously the circumferential line of the possibly smallest space between the profiles.

530b. Model of Weston's Differential Pulley, with weights complete.

Polytechnic School at Halle, Director Kohlmann.

IV. PENDULUMS AND GYROSCOPES.

531. Gyroscope. A mechanical contrivance to exhibit the phenomena of rotation, and to show experiments on the deviation of spherical projectiles. *Elliott Brothers.*

532. Foucault's Gyroscope. Ordinary model.
Geneva Association for constructing Scientific Instruments.

532a. Gyroscope, by Foucault. *College of France, Paris.*

532b. Reuleaux's Ball-Gyrometer.
H. Hädicke, Engineer, Demmin, Pomerania.

The object of the instrument is to indicate the rotations made per minute by any rotating body brought into connexion with the same. The number indicated will be read off a dial. As a remarkable peculiarity it may be mentioned that the scale of the dial shows a uniform division, although the position of the balancing balls moving the pointing hand depends—according to a complicated law—on the velocity of the rotation of the spindle (shafts).

The motion is worked by means of straps and strap disc, and can, as a matter of course (on vessels, &c.), be effected by a fixed connexion with a shaft-movement.

A winch-handle, however, will enable the spectator to put the instrument in motion by the hand.

The accuracy of the indications of the instrument will be augmented if the pointing hand is turned off a little with the finger in the direction of the progressive numbers, and then allows it to jerk back freely.

A forcible turning of the pointing hand in the opposite direction, toward O, is not allowed.

533. The Polytrope. A gyroscope mounted on circles so as to prove the laws of combined rotations about several axes. It may be used to determine the *meridian* or the *latitude* of a place, and to show the rotation of the earth on its axis, and for other experiments.
Wheatstone Collection of Physical Apparatus, King's College, London.

534. "Soldier Experiment." Model designed to demonstrate the relative effects of revolution and of rotation, separate or combined, by the movements of soldiers.
Henry Perigal, F.R.A.S.

535. Compass Experiment, demonstrating that a magnetised needle does, but an unmagnetised needle does not, maintain its parallelism while revolving or orbitating in a circle.
Henry Perigal, F.R.A.S.

536. Gyroscope, demonstrating the effects of revolution and of rotation, the two ways of turning round.
Henry Perigal, F.R.A.S.

537. Gyroscope, demonstrating that revolution (orbitation) alone will account for our always seeing the same face of the moon. *Henry Perigal, F.R.A.S.*

538. Selenoscope, to demonstrate the kinematic effects of the three hypotheses of the moon's motion, as a satellite of the earth. *Henry Perigal, F.R.A.S.*

539. Kinescopes, illustrating the laws of compound circular motion, by ocular demonstrations of their representative curves, shown by bright beads revolving with great rapidity.

Henry Perigal, F.R.A.S.

539a. Pendulum Apparatus, for the graphic representation of the combination of non-rectangular vibrations, with illustrative plates.

Institute for Physical Science of the University of Halle, Professor Dr. Knoblauch.

An apparatus for the graphical representation of two simultaneous oscillations inclined to each other.

To a table are fastened the axle-beds of two pendulums, the oscillation-planes of which are permitted to change their angle of inclination. One of these pendulums transfers its motion to a horizontal bridge, the other to a writing pin which moves exactly above the bridge. The oscillatory directions of the bridge and the writing pin are the directions of the combined velocities. The curve the pin writes down on the oscillatory bridge is to be considered as the trajectory of a point moved across a reposing basis by the simultaneous oscillations of the pin and the bridge.

One fixes this trajectory either by conducting a steel pin over a piece of sooted paper, or leading over a white paper a narrow-pointed glass tube filled with anilin ink.

If the weights at the pendulums are displaced the proportion of their oscillatory movements is altered ; every difference of phase is obtained by an appropriate choice of the time, one pendulum begins to move after the other. In this way the apparatus produces the greatest variety of geometrical figures imaginable.

The tables accompanying the apparatus may serve as specimens, which were drawn by the apparatus.

A more exact and scientific explanation is to be found in the "Zeitschrift "für die gesammten Naturwissenschaften von Dr. C. Giebel," Bd. XIV., October 1875.

The apparatus has been projected by P. Schœnemann in the Royal Seminary of Mr. Knoblanch, Professor of Physics at the University of Halle, and has been executed for the physical science cabinet of the University of Mr. Kleemann, mechanical engineer (Halle, Manergasse 6).

539b. Compensatory Pendulum.

Rohrbeck and Luhme, Berlin.

539c. Tisley's Compound Pendulum Apparatus.

Tisley and Spiller.

539d. Donkin's Harmonograph, for compounding two parallel harmonic motions.

V. VIBRATIONS AND WAVES.

540. Apparatus for the Composition of two parallel simple vibrations. *Dr. F. G. Groneman, Groningen.*

1. Principle. If the point C moves with constant velocity through the circumference of the circle AC, it is known that its projection B upon the diameter GH performs a motion, which is called a simple vibration.

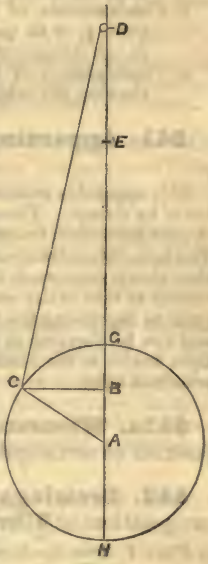


Fig. 1.

If in this variable point B a string is fixed, which is put through the pulley D, and from this hangs down to E, so that BD + DE is the constant length of the string, it is easy to see that the point E will perform quite the same motion as B.

If this string is not attached in B, but in the moving point C itself, E will have a motion which is not strictly, but nearly that of B, the difference resulting from the difference of the two variable lines BD and CD. This difference can be diminished to any degree, by increasing the distance between the pulley and the centre A.

2. Two discs of the same diameter are placed in the same vertical plane, and can turn round the horizontal axes, one of which has a handle. The motion of the first disc is communicated to the second by means of crown wheels and cog wheels. One of the latter can be fixed at any point of its axis, so that it may correspond with each of the six crown wheels of the second disc. By this arrangement the velocity of the second disc can be made equal to that of the first, or the $\frac{18}{17}$, $\frac{4}{3}$, $\frac{3}{2}$, $\frac{2}{1}$, or the $\frac{3}{1}$ part of it. For changing this velocity, or for changing the difference of the phases, when the velocities of the discs are the same, the washer at the end of the axis of the second disc must be a little loosened, and this axis pushed forward.

3. The discs have one knob each. If the distance of the knob of the first disc to the centre of it is called 1, that of the knob of the second disc can be made 1, $\frac{1}{2}$, or $\frac{1}{10}$. From the knobs proceed two strings, which are put through the pulleys on the top of the instrument, and bear the hooks A and B (Fig. 2).

It is easy to understand that these hooks, when the handle is turned, perform two simple vibrations, the one being invariable, the other variable, in amplitude, phase, and velocity.

4. From A and B proceed two strings, passing through the pulleys C and E, and fixed in F and H. These pulleys have strictly the same motions as A and B, at a rate of one half. A third string proceeds from A to B, passing through D. At any moment the displacement of D will be the sum of the displacements of A and B, at a rate of one half. Its motion is therefore the resultant of those of C and E.

The motions of the three pulleys are shown by the little white balls, placed on the front of the instrument.

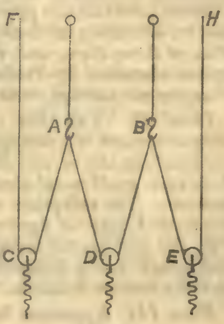


Fig. 2.

5. With this apparatus an infinite number of combinations can be demonstrated. I will mention only four:—

a. Two vibrations of the same amplitude and velocity, no difference of phase. The middle ball has double the amplitude.

b. The same, the difference of phase being 180°. The motion of the middle ball is nearly zero. The deviation that will appear results from the difference in the length of BD and CD (Fig. 1).

c. Combinations of a tone with one of its harmonics 2 and 3 with its quint $\frac{3}{2}$, or its quart $\frac{4}{3}$, as well as when they are of the same intensity or not (theory of the timbre).

d. Combinations of two tones of the same intensity, with the interval $\frac{18}{17}$, showing the origin of beats.

541. **Apparatus,** of a new form, to illustrate **Wave Motion.** *C. J. Woodward.*

This apparatus consists of a series of balls suspended from a horizontal beam by strings. These balls rest against a series of partitions in a wedge-shaped horizontal trough, which can be raised and depressed parallel to itself. The box, being drawn on one side in the plane in which the balls hang and then slowly depressed, the balls will be successively liberated, and a wave, similar to that of the sound wave, produced. If the beam be drawn aside prior to depressing the box, the balls will rest against one side of the trough and can be liberated in succession, causing them to oscillate in a plane at right angles to the beam, a vibration being produced similar to that of plane polarized light.

541a. **Wheatstone's Apparatus,** for illustrating the composition of rectangular vibrations. *Council of King's College.*

542. **Drawings of new Apparatus** for demonstrating the composition of **Vibrations.** *Dr. Leopold Pfaundler, Innsbruck.*

Plate I. Two blackened glass discs are each placed on a separate horizontal axis one before the other, in such a manner that the transparent curves apparently cut in their periphery, intersect each other at nearly right angles. A reflection of light is produced thereby, which, at the revolution of the discs, will generate figures such as are caused by the complex effect of the vibrations acting at right angles upon one another. By a simple mechanical contrivance the velocity of the rotary motion of each of the discs can be regulated according to equally simple relative relations. Thereby the figures of the different intervals are produced. By varying the tension of the strings more or less, an alteration in these places will be achieved. By changing one or the other of these discs, and replacing it by another with a different curve, the figures observed by Professor Dr. Helmholtz, on oscillating strings with the vibration microscope, will be obtained, instead of those of Lissajous.

Plate II. Two thin rods of steel are fastened by screws at the two oblique corners of a strong bar of iron in such a manner that their further ends, one reaching above the other, vibrate vertically the one upon the other. To these ends small metal plates (discs) with incised slits are attached in a parallel position. The reflection of light produced by the intersection of these slits will show Lissajous' figures. A movable weight regulates the intervals.

B, the well known *tuning-fork apparatus* with mirrors is simplified by the tuning-fork being replaced by steel springs which are inserted in suitable movable wooden columns.

Plate III. Apparatus for simplified demonstration.

A. ramified tuning-fork.

The same produces a sound composed of two tones, and marks the corresponding musical note direct on a sooty glass plate.

B, resonator with monometrical flame without membrane.

In a conical shaped Resonator, which is held with the large opening downwards, illuminating gas is filled from the top, which is allowed to escape through an attached small tube and then ignited. The flame will react on the tones (sounds) in the usual manner.

C, an igneous Kaleidophon.

Mr. Assistant Tollinger has shown that by fastening with wax a glimmering candle to the end of a prismatic steel spring, a very commendable demonstration for large auditories can be produced of this well-known experiment.

542a. Apparatus for **combining waves** in one plane. The resultant shown is that of two sets of waves (superposed) that differ by half a wave-length. *Chas. Brooke, F.R.S.*

542b. Apparatus for **combining waves** in two planes perpendicular to each other. The resultant shown is a right-handed elliptic helix. *Chas. Brooke, F.R.S.*

543. Stationary Liquid Wave Apparatus and Sector Pendulum. *Frederick Guthrie, F.R.S.*

When such a system of stationary waves is formed in a cylindrical deep trough that the centre rises and falls as the edge falls or rises, the undulation is synchronous with a pendulum whose length is equal to the radius of the trough ; and the accelerations of motion of the wave and pendulum are identical.

544. Wheatstone's Wave Apparatus. A very complete instrument, showing plane, circular, and elliptical waves, the phenomena of interference, &c. *Elliott Brothers.*

544a. Apparatus to illustrate **Wave Motion.** *Rohrbeck and Luhme, Berlin.*

545. Illustrations of Vortex Motion. Nos. 1 and 2 are vibrations ; Nos. 3–5 steady motion. (Proceedings of Royal Society of Edinburgh, 1 November 1875.) *Sir William Thomson.*

Series of 11 successive figures of a simple vortex ring, performing violent transverse vibrations of the first fundamental mode.

No. 2. Series of 11 successive figures of a simple vortex ring performing violent transverse vibrations of the second fundamental mode.

Motion analogous to that of screw propellers backing the vortex cone, being in each instance as it were the edge circumference of the screw propeller.

No. 3. Two-bladed screw.

No. 4. Three-bladed screw.

No. 5. Four-bladed screw.

No. 6. Trefoil knot described in Sir W. Thomson's papers on vortex motion. Transactions of Royal Society of Edinburgh for 1857 and 1858, and figured on the back of the "Unseen Universe," by Professors P. G. Tait and Balfour Stewart.

VI. FALLING BODIES AND PROJECTILES.

546. Drawing of a new Apparatus for demonstrating the lateral deflection of rotating conic projectiles.

Dr. Leopold Pfaundler, Innsbruck.

The conic projectile A turns within the horizontal frame B on its own horizontal axis, and can be put in rotation by pulling off the reel the string attached to *a*. Fastened, on the outside of the frame, on two little hooks, *b*, *b*, whose line of communication is perpendicular to the axis of rotation and passes through the centre of gravity of the entire body, are two threads, which join further up, and whose combined continuation reaches up and is tied to a hook in the ceiling.

At the back there is a steering wing C with a counter-weight D, attached in such a manner that according to the position in which it is placed the effect of the atmospheric resistance will be located either above or below the centre of gravity of the projectile, without, however, altering the position of the centre of gravity itself. The wing can be turned on its axis, or be removed and replaced by a double wing C^1 with the two flat surfaces situated vertically to each other.

The following experiments can be made with this apparatus :

1. *Stability of the Axis of Rotation.*

The apparatus is put in motion to swing in a curve of five meters length by taking hold of the wing and pulling it backwards, and then allowing it to drop. If the projectile does not rotate, it easily turns over and will deviate from its course by very slight causes ; if it rotates, it will remain parallel with its axis. The wing must be given a neutral position in regard to the atmospheric resistance.

2. *Lateral Motion.*

The apparatus is made to rotate to the *right* by the wing C being placed in an *upward* position, when the point in flying forwards will revolve to the *right*. If the direction of the rotation, or the position of the wing, be altered into the opposite course or direction, the point will revolve towards the *left*. If both are changed, the rotation will keep in the direction to the *right*.

3. *Lateral Deflection.*

The single wing C is replaced by the double wing C^1, the flat surfaces of the same being placed in a vertical and horizontal position, and the proceeding then is the same as described before.

Instead of the lateral motion, a parallel lateral deflection will be the result.

The latter experiment corresponds to the actual motion of the projectiles. The greater degree of velocity of the same is equalized by the larger surface of the wing as regards the atmospheric resistance.

547. Simple and Inexpensive Form of Morin's Machine for demonstrating the law of falling bodies. It can be made by an ordinary carpenter, at a moderate price.

Made and exhibited by Dr. Stone.

548. Apparatus by General Morin for the experimental demonstration of the laws of falling bodies.

M. Digeon, Paris.

549. Attwood's Machine with water clock attached.

The Council of the Yorkshire College of Science, Leeds.

The time is measured by a water clock, the orifice of which can be opened by means of a lever moving under the influence of an electro-magnet. The weights are supported by a thread grasped by a pair of iron pincers, which are kept shut by a spring, but can be opened by means of another electro-magnet included in the same circuit as that attached to the water clock, so that the water begins to flow and the weights to fall simultaneously. Another metal piece can be screwed on to the instrument. One of the binding screws with which it is furnished is insulated from it by a plate of ebonite pierced with a shut metallic rod in connexion with the binding screw, and on which rests one extremity of a lever in electric communication with the rest of the piece. This piece being included in the circuit the current cannot pass when the lever is raised, and the water clock is stopped as soon as this is effected by the falling weight.

549a. Attwood's Machine, with friction rollers and electro-magnetical release. *Ferdinand Ernecke, Berlin.*

549b. Attwood's Machine, with pendulum attached.

Rohrbeck and Luhme, Berlin.

VII. FRICTION.

550. Apparatus for determining the Friction between Water and Air.

Professor Viktor von Lang, Vienna University.

The above consists of a heavy stand with one fixed and three movable arms. The fixed arm bears a short glass tube, from which a continuous stream of water is made to flow. A crosspiece of four glass tubes is united, air-tight, by its longest arm to the water-delivering tube; the opposite arm is directed downwards, and closed by a caoutchouc mouthpiece passing over the "aspirating tube." This latter is supported by the two lowest arms of the stand, the remaining fourth arm securing the crosspiece. The stream of water passing through the "aspirating tube" moves the air, the quantity of which is determined by the motion of a soap lamina in the "measuring tube." This tube is joined to one of the horizontal arms of the crosspiece, the fourth arm bearing a water manometer.

550a. Machine for the **Examination** and **Measurement** of the **Sliding Friction** caused by the **Motion** and the **Variable Velocity** on **Rails.** Constructed by Herr Jung, at the University of Giessen.

This machine includes :—

a. A board, with hooks for attaching a scale by means of a cord running on a roller, for the purpose of measuring the friction.

b. Two pairs of iron and brass rails, to be fixed to this board.

c. Three pairs of wooden rollers.

d. A pair of iron rollers.
e. A pair of brass rollers.

Institute for Physical Science of the University of Giessen; Professor Dr. Buff.

This apparatus was originally used for measuring gliding friction. It is at the same time a convenient appliance for demonstrating the friction of the steam engine on the railway line.

SECTION 5.—MOLECULAR PHYSICS.

WEST GALLERY, UPPER FLOOR ROOM (Q).

I. SPECIAL COLLECTIONS.

STANDARDS OF THE HYDROMETERS AND THERMOMETERS USED BY GOVERNMENT OFFICERS IN HOLLAND.

Exhibited by Dr. J. W. Gunning, Professor of Chemistry at the "Athenæum illustre," Amsterdam.

579. General Hydrometer (No. 1), with open stem and variable weight. Every degree has a bulb equal to $\frac{1}{100}$ of the part of the hydrometer below zero. When this instrument, having the arbitrary weight = W, marks a degrees in a liquid, the apparent specific gravity of that liquid at the observed temperature will be $= \frac{W}{(100 + a)1{,}014{,}608}$.

580. Instruments (Nos. 2 and 3) for ascertaining the strength of alcoholic liquors. The degrees are the same as in No. 1, but the weight is not variable, and the zero is the immersion point at 15° C. in a liquid, of which the specific gravity at that temperature is equal to the specific gravity of pure water at 4° C. Tables are added, those of Professor von Baumhauer (1863), used in Holland; those of the exhibitor (1873), used in the colonies. The latter are based on the researches of Mendelejeff. Philos. Mag. (4) XXIX. 395.)

581. Hydrometer (No. 4), for liquids of a specific gravity greater than 1. The construction is the same as in Nos. 2 and 3. The Beaumé scale is added. Used for solutions of salts and sugar juices.

582. Hydrometers (Nos. 5 and 6), for ascertaining the specific gravity of seed oils and of petrol, allowing immediate application of correction for temperatures, other than 15° C. (For description see Scheik. Bijdragen door J. W. Gunning, Amsterdam, 1867.31.)

583. Densimeters (Nos. 7, 8, and 9), with flat stems. The zero is the same as in Nos. 2 and 3.

584. Hydrometer (No. 10), for preparing a liquid having at 15° C. the specific gravity of pure water at 4° C. The instrument is made in the following manner:—Through the open stem shot is introduced till the instrument floats at the mark on the stem in pure water of 15° C. The weight of the instrument is then increased in the ratio 0·99915 : 1, in consequence of which it floats at the same mark at 15° C. in a liquid having at that temperature the specific gravity of pure water at 4° C.

The thermometers have the Celsius' scale. By their mode of construction they possess the following advantages: (1.) They may be turned upside down and shaken in any manner without breaking the column of mercury. (2.) Though newly made, the zero is not subject to displacement.

The former advantage is obtained by filling the tube and the upper recipient with perfectly dry, dust free air, as highly compressed as possible.

The latter advantage is secured by placing the bulbs of the newly made thermometers in a bath of paraffin, heated slowly to 100° C. and then allowed to cool slowly and in succession sixty to a hundred times.

585. Trough for comparing Hydrometers.

II. AIR PUMPS AND PNEUMATIC APPARATUS.

586. Hand Pump, Regnault's System improved.
Geneva Association for Constructing Scientific Instruments.

Sucking and forcing hand pump. The hand pump, constantly used in laboratories, has now attained a satisfactory practical shape, from which not much deviation is possible. Its general proportions are determined by the consideration of what best use can be made of muscular power, and also of the simplicity and facility of carriage of the apparatus. Silken valves, as being too perishable, are excluded and replaced by cones of metal and leather. All the moveable parts, piston and valves, are equally accessible. Three cocks effect the complete cutting off of all communication between the pump and the exhaust pan and the compression pan, as well as restore direct communication, either between both or one of these and the atmosphere. If rarefaction is required in the compressing vessel, or *vice versâ*, without disturbing the tubes of communication, the relative position of the valves must be inverted, which may be done in a few minutes, or else a commutative cock must be joined to the pump.

For effecting all communication between the pump and its recipients, a screw flush joint is always used, which is very safe, and can be adjusted to tubes made of india-rubber, copper, or lead. This avoids the deterioration of the india-rubber, which is unavoidable on account of the constant action of the fastening joints, especially as it is rarely that a thoroughly air-tight joint can be made with india-rubber alone.

588. Sprengel's Mercury Pump.
The Director of the Physical Laboratory of the University of Groningen.

This instrument differs from all others—(1) in the numerous curvatures of the tube through which the mercury falls. These augment the evacuating power of the pump, while the air bubbles, which are carried away with the mercury, and which, when near vacuum, are so minute that they remain hanging on the walls of the tubes before coming down, assemble in the curvatures, until their size is so far augmented that they are carried away by the falling mercury. (2) The instrument is provided with a peculiar stop-cock with two perforations, whereby the flowing of the mercury is regulated and the acquired vacuum preserved. To effect this, the stop-cock is furnished with two iron rings, which float on the mercury, and, falling with it, close the opening of the stop-cock. By means of the second perforation of the stop-cock the instrument can be joined to an ordinary air pump, and the operation abridged by a partial exhaustion of the air. To produce a more complete vacuum than can be obtained by an ordinary air pump, the stop-cock is turned half round, and, when the vessel surrounding the stop-cock is filled with mercury, Sprengel's air pump begins to act.

589. Aspirator, moved by clockwork and sulphuric acid; U tube for determining accurately the amount of moisture in the atmosphere by the use of the balance. *Dr. Andrews, F.R.S.*

The amount of moisture at different periods of the day, or the average amount in 24 hours, may be determined with great precision by means of this arrangement, which Dr. Andrews proposed many years ago for use in meteorological observatories, instead of the present defective methods.

590. Spirator. Designed to get a constant current and measureable volume of air driven or drawn over a body.
Frederick Guthrie, F.R.S.

The principle resembles that of "Tantalus' cup." A constant current of water enters a flask, and (1) drives out its own volume of air through a mercury trap; (2) when the flask is filled up to a certain point, a siphon acts, and, in emptying the flask, draws air in from another tube.

591. Small Wooden Model of Mr. Colladon's new Air and Gas Compressors (patented), used for the great Gothard Tunnel. *Professor Daniel Colladon, Geneva.*

This system of compressors refrigerates air and gases simultaneously with the compression, and all the moveable parts are kept cold, whatever may be the rapidity and force of compression. This system has been applied to several industrial purposes. It is the system of air compressors used exclusively in the boring of the great Gothard tunnel (length 14,920 mètres). At the extremity of this tunnel 30 of these compressors give 40 cubic mètres of air per minute, under the pressure of seven atmospheres, for the aëration of the tunnel, and the working of 60 boring machines and other apparatus, and eight other compressors supply air of 14 atmospheres for compressed air locomotives. *See* **2060.**

597. Air Pump, by Otto von Guericke, with stand.
Professor Dr. Lepsius, Berlin.

606. Otto von Guericke's original Air Pump.

"*Collegium Carolinum,*" *Polytechnic School at Brunswick, Professor Dr. H. Weber.*

The earliest reliable information respecting *Otto von Guericke's* original apparatus is contained in a list of the physico-chemical apparatus of the *Collegium Carolinum*, at Brunswick, of the year 1816. In this list it is stated that these apparatus were obtained from the inheritance left by Aulic Councillor *Beireis*, in Helmstedt. According to a special ordinance of His Highness *Frederich Wilhelm*, Duke of Brunswick, dated 8th October 1814, the collection of physical, mathematical, and astronomical instruments derived from the inheritance left by *Beireis*, physician in ordinary, at Helmstedt, was exhibited in the rooms, and by a later ordinance dated 9th March 1815 incorporated with the collections of the ducal *Collegii Carolini*. The air-pump has been preserved unaltered, with the exception of the lever and the piston attached to it, the former having been replaced by a new one of the same construction, and the latter by a wooden one, in the year 1864. The pump has been described and faithfully represented by a drawing in a work published by *Otto von Guericke*, entitled "Ottonis de Guericke Experimenta nova (ut vocantur) Magdeburgica de vacuo spatio Amstelodani," 1672, cap. IV. p. 75, Tab. VI., in which work he also (p. 122) successfully refuted the assertion of *Augustus Hauptmannus*, doctor of medicine, in his "Berg-be-deneken, anno 1658, Lipsiae," "that it would not be possible to either angel or devil to bring about a vacuum." This work is in the possession of the ducal library, at Wolfenbüttel. But, previous to this air-pump, *Otto von Guericke* had constructed one more simple, consisting of only one cylinder and a piston, which is said to be in the library at Berlin. The difficulty, however, connected with the motion of the piston, the resistance of the air against the free piston being so great that it required two strong men to pull it out repeatedly, p. 75, induced him to contrive their second improved construction. The air-pump plateau at present in use was unknown to *Otto von Guericke*. In order to produce a vacuum, he employed a hollow copper ball with stop-cock,* which was placed on the pivot of the barrel. It was evacuated, and screwed on to other vessels, whereby, by repeating this manipulation, the latter was evacuated likewise. The pail of tin-plate attached to the lower end of the barrel, as well as the copper bowl fastened to the upper end of the barrel, were filled with water or oil, in order to effect thereby a greater tightness.

622. Diagram of Von Guericke's Air Pump. Invented 1654. *A. Galletly, Edinburgh.*

It consisted of a globe of copper, with a stopcock, to which a pump was fitted.

The pump-barrel was entirely immersed in water to render it air-tight. This was the earliest of all air-pumps.

623. Diagram of the First English Air Pump, constructed in 1658–59 by Hooke and Boyle, but mainly by the former.
A. Galletly, Edinburgh.

As shown in the diagram, it had a single barrel, in which was a piston worked by a rack and pinion. In working it the valve G of the cylinder was

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* This ball (page 88, Tab. VIII.), as well as a pair of still larger Magdeburg hemispheres, nearly an ell, Magdeburg measure, in diameter, which 24 horses had not the power to separate (page 105), and, lastly, a copper boiler with inserted piston, which, when the air below the same was withdrawn, 50 men were not able to lift or to pull up (page 109, Tab. XIV.), are likewise enumerated in the list, but no longer to be found.

shut, while the stopcock L of the receiver was open, during the descent of the piston. When the piston was driven home, L was shut and G kept open. In this air-pump a vacuum was produced slowly, and was imperfect at best.

587. Air Pump, with double barrel (1662), by Boyle.

Royal Society.

624. Diagram of the Second English Air Pump, constructed by Boyle and Hooke in 1667.

A. Galletly, Edinburgh.

The piston was worked by a rack and pinion like the first English air-pump, but in this one the barrel was kept under water to keep the leather of the piston always wet.

The piston had an aperture at F and a stop-cock at I, which were worked as in the first English air-pump.

625. Diagram of Papin's Air Pump. 1676.

A. Galletly, Edinburgh.

The diagram represents only the working parts of the instrument, without the frame supporting them. This air-pump had the great advantage over earlier forms of having two barrels, in which case, as the air becomes exhausted, the resistance which it offers to the ascent of one piston is nearly balanced by the force with which it compels the other to descend. This air-pump was worked by moving the feet alternately up and down in stirrups.

618. The Abbé Nollet's Air Pump.

Conservatoire des Arts et Métiers, Paris.

626. Diagram of Hauksbee's Air Pump. 1703–9.

A. Galletly, Edinburgh.

This instrument, like Papin's, had two barrels, but the stirrup arrangement and pulley are replaced by racks on the piston rods, and a pinion moved by a handle, as in the modern double-barrelled air-pump.

612. Apparatus for Air Pump. An air-gun supported by two vertical mahogany pillars and cross-bar, by means of which it may be adjusted to any angle.

Museum of King George III., King's College.

613. Apparatus for Air Pump. Metal condenser with glass ends, large enough to take a pair of four-inch Magdeburg hemispheres with fittings, and a metal lever to which weights may be attached to measure the pressure of the air, either when compressed or at its ordinary pressure.

Museum of King George III., King's College.

614. Air Pump with two Barrels. The first pump of the kind ever constructed. It is an exhausting and a condensing pump, and was made for King George III. in 1761.

Museum of King George III., King's College.

592. Drawing of Mercurial Air Pump (1872).

J. P. Joule, D.C.L., F.R.S., Manchester.

By alternately lifting and lowering the bulb attached to the flexible tube, and drying the air by the admission of sulphuric acid through a glass valve at the upper part of the perpendicular tube, a very excellent vacuum may be obtained in a short time.

592a. Improved form of **Sprengel's Mercurial Air Pump.**
E. Cetti & Co., Brooke Street, Holborn.

593. Mercury Air Pump. *Dr. H. Geissler, Bonn.*

594. Photograph of an Air Pump, the exhibitor's construction (in frame).
C. Staudinger and Co., F. W. von Gehren, Giessen.

594a. Photograph of an Air Pump, the exhibitor's construction (in frame).

This air-pump has a double-acting barrel of 10 cm. diameter and 32 cm. in height. The motion of the piston is effected by the rotation of a fly-wheel in one direction.

595. Hydro-dynamical Air Pump.
Baron Dr. von Feilitzsch, Professor at the University of Greifswald.

An ordinary air-pump receiver communicates with a tube through which mercury is passed with great rapidity in such a manner as to flow in through a small aperture and to flow out again through a wide opening. A vacuum will thus be produced under the receiver.

596. Mercury Air Pump, with valve, on Mitscherlich's system. (*See* the accompanying treatise.)
Professor Dr. Mitscherlich, Münden, Hanover.

(See "Poggend Ann. of Chemistry and Physics," vol. 150, p. 420.)

598. Two Magdeburg Hemispheres.
Professor Dr. Lepsius, Berlin.

599. A book : **"Ottonis de Guericke Experimenta nova** (ut vocantur Magdeburgica) **de Vacuo spatio."** Primum a R. P. Gaspare Schotto e Societate Jesu et Herbipolitanae Academiae Matheseos Professore : nunc vero ab ipso Auctore perfectius edita, variisque aliis Experimentis aucta. Quibus accesserunt simul certa quaedam de Aeris Pondere circa Terram, de Virtutibus mundanis, et Systemate mundi planetario, sicut et de Stellis fixis, ac Spatio illo immenso quod tam intra quam extra eas funditur.

Amstelodami apud Joannem Janssonium à Waesberge, Anno 1672. Cum Privilegio S. Caes. Majestatis.
Professor Dr. Lepsius, Berlin.

600. Air Pump. *Charles Gustavus Pinzger, Breslau.*

This air-pump is provided with a double acting piston, and so arranged that it can be used as evacuation and as compression pump. In the former case

the barrel is placed in a diagonal position, and the pump provided with glass plate and stop-cock, but if the plate with the cock be screwed off, and the hose-screw attached to the wooden stand screwed on, and the barrel detached from its support and placed perpendicularly, the pump can in that case be used as a compression pump. Plate with cock are meanwhile screwed again on the wooden stand. The cock below the barrel, by reason of its parallel position, effects with this the connexion between barrel and plate, and in its upward position, the communication between barrel and the external air; and, lastly, in its downward position, the communication between the plateau and the external air.

601. Mercury Air Pump, on Professor von Jolly's system,
Professor von Jolly, Munich.

This air-pump has been described by G. Jolly in Carl's Repertorium, 1865. As regards the alterations which have since taken place, and which have been introduced in the apparatus exhibited, a special description has been added to the object.

602. Apparatus for proving Mariotte's and Dalton's Law.
Professor Baron Dr. von Feilitzsch, University of Greifswald.

Whilst, commonly, two different apparatus are employed for demonstrating, for a larger or a lesser pressure than one atmosphere, the laws in question, this inconvenience has been remedied by the present apparatus. A glass tube open at the upper end, and a gauged glass tube, which can be closed at the upper end by a stop-cock, communicate by means of a long gutta-percha tube, can be displaced on a vertical scale, and are partly filled with mercury. The latter tube contains the gas to be tested, or the combination of gases and vapours, and by raising or lowering of the first tube, the level of the mercury will be changed as required, and the volume of gas resulting therefrom indicated.

The apparatus can be easily employed, if suitably altered, for all kinds of experiments, at which different pressure, or a reduction to the atmospheric pressure is required; for instance, in atmospherical thermometers, &c.

603. Air Pump, by J. van Musschenbroek, and two Magdeburg hemispheres.
The Royal Museum at Cassel, Dr. Pinder, Director.

1. *Air-pump, with obliquely placed cylinder, on Senguerd's system.*

This air-pump is, perhaps, the oldest of the kind existing, with a doubly perforated stop-cock, as will be seen by the following explanations. It was constructed in the year 1786, by *Jan van Musschenbroek*, in Leyden; nor is it wanting in the Musschenbroek's emblems, namely, the "*Ostor* lamp," and the crossed keys; the armorial bearings (*i.e.*, coat of arms) of the city of Leyden. The invention of the doubly perforated stop-cock, notoriously originated with *Senguerd*, who, from the year 1675–1724, was professor at Leyden. The air-pump, which is preserved in the Physical Science Cabinet of that town, and which, according to the inscription, was constructed by *Samuel Musschenbroek*, in the year 1675, and which has a doubly perforated stop-cock, which is considered there as the first of the kind, could not at first have been provided with it, as it was invented at a later date. It has been, with its component parts, applied to it only at a later period. *Senguerd* has described that kind of cock for the first time in the second edition of his "Philosophia

Naturalis," which was published at Leyden in the year 1685. In his work, "Rationis atque Experimenta Connubium," which was published at Rotterdam in the year 1715, he states that he made the invention in 1675, and that in 1679 he had the air-pump executed by a skilful artizan. That this artizan was *Samuel Musschenbroek* is proved by a notice in the handwriting of *Petrus van Musschenbroek*, which he wrote in a copy of his work entitled, "Beginselen der Natuukunde." However, *Senguerd*, in the first edition of his work, "Philosophia Naturalis," which appeared in 1680, and of which a copy is in the possession of the Library of the University at Utrecht, makes no mention yet of the cock. He has therein an illustration of an air-pump of the original construction of *Otto von Guericke*. That, however, the air-pump was constructed is plain, by a record of *Uffenbach's*, who, in describing the "Laboratorium Phyricum" of the University of Leyden, stated on the 19th January 1711 :

"In the centre stood also an elevated table. Upon this table there stood an 'Antlia pneumatica' of considerable size, of *Samuel Musschenbroek's* old invention, inclined with a 'cista' to put water in." Although the words "of the invention of *Sam. Musschenbroek*" may also be applied or have reference to the air-pump, which is still preserved in the Physical Science Cabinet at Leyden, yet the description does not tally with it, inasmuch as its cylinder is perpendicular, and stands next to an elevated table which carries the plate, and is consequently united with it in one apparatus. It is possible that *Uffenbach*, who was not an adept in that science, was only induced to making the above-mentioned expression by the sign of the firm of *S. v. Musschenbroek*. But how it happened that he did not see the other air-pump, since he mentions yet another still existing air-pump of *Boyle's* construction, is rather obscure, as *De Volder*, *Senguerd's* predecessor in the professorship of physics at Leyden, who himself has laid the first foundation for the establishment of the Physical Science Cabinet at Leyden, must have worked in the same laboratory. "As we were assured," continues *Uffenbach* in his narratives, "there are given here (in the laboratory) 'Lectiones publicæ' four times a "week by *M. Senguerd*, *De Volder*, however, it was stated, has had more "auditors, as he was also more artful ('curieuser') in his experiment."

Senguerd delivered those lectures not until after *De Volder's* retirement, in 1705. *De Volder*, however, died in 1709, and it is possible that the air-pump was at that time in course of reconstruction. *Senguerd's* air-pump, therefore, as it is not to be found in the Physical Science Cabinet at Leyden, must, in all probability, have been private property ; and it is possible that, like many old instruments, it is still somewhere in private possession in Holland. So long, however, as it is not discovered, the Museum at Cassel may lay claim to the distinction of having in its possession the air-pump with the oldest doubly-perforated stop-cock. For although *Senguerd* had his air-pump made in 1679, the description of the same did not appear until 1685, which indeed excited much attention at the time. Christian Wolff, in 1718, had one constructed exactly according to the same pattern, by Leupold at Leipsic, which may still be seen in the Physical Science Cabinet of the University at Marburg. Very singular indeed it is that Musschenbroek, in his manifold writings, never as much as mentions Senguerd's air-pump. That, of course, this omission cannot be constructed into an argument as against the priority of *Senguerd* is plain by the subsequent remarks in the above-mentioned autograph notice, in which it is stated that "in the year 1679 "*Mr. Senguerd* considered with the same *Samuel Musschenbroek* air-pumps "of another kind, which afterwards were improved by my father, *Jan van* "*Musschenbroek*, as well as by my brother" ("in den jaare 1679 heeft de "Heer Senguerd met dienzelven *Samuel Musschenbroek* hucht pompen van "een anderen aart bedagt, welke geduurig naderhand door mynen vader

" Jan van Musschenbroek, als door mynen broeder verbeterd zyn.") It seems as if family partiality had influenced him.

The air-pump is accompanied by two powerful Magdeburg hemispheres with which at Cassel the experiments of Otto von Guericke, of the Regensburg Diet, were repeated.

604. Compression Machine.

The Royal Museum at Cassel, Dr. Pinder, Director.

The Compression Machine for throwing bomb shells (air-mortars).

This is one of the most ancient instruments that are in the possession of the musem at Cassel. On the 16th November 1709, already von *Uffenbach* had seen it in the Art Museum of Landgrave *Karl.* It was to serve for the purpose " of throwing grenades, when already lighted, through the air for a " distance of more than a 100 yards, with the usual effect." At that time it had just been repaired of some of its former defects. " Twelve grenades can " be thrown one after another with great rapidity. But, because as the air is " continually diminishing, the last ones, as may be easily conceived, do not " go as far as the others." This instrument, which acts on the principle of an air-gun, and by which also red hot shots could be thrown without any danger to the men serving it; the brass ball carried a funnel upon which the grenades were placed—is so far of historical interest as it is a surviving witness of the joint labours of *Papin* and the Landgrave *Karl,* and it even transports us in the midst of that catastrophe, which put an end to Papin's activity. A similar machine, with which *Papin* contemplated throwing bomb shells by means of steam, it was which exploded in his laboratory. " The other and " greatest misfortune was that, as he had undertaken to shoot the same with " water as with powder, he might easily have done great mischief, for as the " machine prepared for that purpose exploded, not only a great part of the " laboratory was demolished, several men mortally wounded (one among " whom had his jaw-bone carried away), but even Landgrave Karl himself, " who is a very curious lord, intent upon seeing and examining everything " minutely, might have been hit, and have lost his life, if not His Highness had " been detained by mere accident by other affairs and come to the laboratory " later, on which occasion Papin was dismissed from his service."

605. Suction Pump, on an iron stand.

Ferdinand Ernecke, Berlin.

605a. Suction Apparatus. Two small pieces of apparatus to illustrate the deficiency of pressure attending a high velocity in a stream of air. *Lord Rayleigh.*

By blowing through the electrotyped copper tube a suction of 6 inches of mercury may be realised at the narrow part.

In the second arrangement the novelty consists in the cap at the end of the brass tube, by which the efficiency is increased.

607. Two large Magdeburg Hemispheres of copper.

Professor Dr. H. Weber, Brunswick.

The two large hemispheres of copper are those of which *Otto von Guericke* states, in page 104, Tab. XI., that after their evacuation they could not be separated by the united strength of 16 horses. They have a diameter, as mentioned in the work alluded to above, of nearly $\frac{3}{4}$ Magdeburg ells, or, according to a second more exact statement, 0·67 Magdeburg ells.

The two smaller hemispheres of brass were used for experiments with weights (page 106, Tab. XII.).

608. Two smaller Magdeburg Hemispheres of brass.

Professor Dr. H. Weber, Brunswick.

609. Double Cylinder Air Pump, with Babinet's stop-cock, cylinder 170 mm. high, 60 mm. wide, with manometer and glass plate of 200 mm. diameter, on a mahogany board, with the following auxiliary apparatus :—

1. A pair of Magdeburg hemispheres of glass.
2. An electric egg, consisting of two parts, with arrangement for carbon points.
3. A double mill.
4. Balloon, with bell.
5. Balloon, for the gravity of the air.
6. Fountain.
7. Quicksilver.
8. Ring.
9. Dasimeter.
10. Falling tube.
11. Heronsball.

Warmbrunn, Quilitz, and Co., Berlin.

610. Apparatus for Lighting, on the system of Döbereiner, with contrivance for drying the gas.
Warmbrunn, Quilitz, and Co., Berlin.

610a. Water Vacuum Pump, invented by H. Sprengel in 1863. *Hermann Sprengel.*

610b. Air Pump, by Handinger, at Ajiessen.
Chemical Laboratory University of Berlin; Professor A. W. Hofmann, Director.

611. Water Pump, either for exhausting or for compressing air. *Joseph Conquet.*

This apparatus can be used either in place of an air-pump, or in place of bellows. Water at a pressure of two atmospheres is required for working it.

615. Apparatus for Air Pump. Cylinder machine with leather rubbers. The apparatus is so constructed that the cylinder may be enclosed in a large glass receiver, which can be exhausted.
Museum of King George III., King's College.

616. Large Air Pump, arranged for effecting the ordinary vacuum or the dry vacuum to a millimetre on the column of mercury, and also for producing ice. *M. Carré, Paris.*

616a. Small Air Pump, also capable of being transformed at will into a compression pump. *M. Carré, Paris.*

617. Apparatus for producing ice by vacuum and sulphuric acid. *M. Carré, Paris.*

619. Hydraulic Press of Copper and Glass (for demonstration). *Luizard, Paris.*

620. Apparatus for Compression. *Luizard, Paris.*

620a. Model of an Air Compressor, which may also be used as a water meter. *M. Eugene Bourdon, Paris.*

621. Air Pump for Double Exhaustion (Babinet's principle). *Luizard, Paris.*

621a. Model of Pneumatic Machine.
M. Loiseau, jun., Paris.

627. Fick's Spring Manometer. *Weber, Würzburg.*

628. Portable Pneumatic Apparatus.
Prof. Waldunberg, Berlin.

This apparatus serves for condensing and rarefying air for medico-therapeutical and physiological purposes. It is possible by its means—

1. To inspire during its use compressed air whose degree of compression remains constant, but the compression of which can be varied to any extent by means of a known weight lying on it.
2. To exhale into rarefied air whose rarefaction is known and can be varied by means of the superimposed weight.
3. To inspire rarefied air.

These three methods of action not only produce a certain mechanical effect on the organs of respiration, but also affect the heart and the circulation. The apparatus is therefore adapted for studying the physiological action of compressed and rarefied air on the circulation and respiration.

Especially, however, it serves for medico-therapeutical objects, for which its mechanical action renders it applicable; as, 1, the inhalation of compressed air; 2, exhalation into rarefied air; and, 3, inhalation of rarefied air. As a remedy it is suitable for a series of lung and heart diseases; as, for example, the exhalation into a rarefied atmosphere has been ascertained to be beneficial in many cases of emphysema of the lungs and asthma. The inhalation of compressed air in the treatment of pleuritis, bronchitis, and dyspnœa, &c.

629. Pneumatometer. *Prof. Waldunberg, Berlin.*

630. Air Pump, made by Spencer & Sons, Dublin.
Prof W. F. Barrett.

630a. Single Barrel Air Pump.
James How and Son, London.

III. OSMOSE, DIALYSIS AND DIFFUSION.

631. Electric differential Osmometer. Engelmann.
Prof. Engelmann, Utrecht.

Two glass vessels of quadrangular section, possessing in the plane ground surfaces facing each other a round aperture 30 mm. diameter, and each containing an electrode; a platinum disc 30 mm. diameter. Between the two vessels the cell is placed, a plane parallel plate of ebonite, furnished with a transversal perforation 30 mm. diameter, communicating with a short brass top, upon which a rise-tube, manometer, etc. can be screwed. The mem-

branes or porous plates, whose electric osmetic permeability is to be compared, are placed between the cell and the glass vessels, the whole secured by two brass vices. Both vessels and the cell are now filled with the same fluid. Non-elastic partitions (clay plates, f. i.) must, in order to prevent breakage and leakage, be provided, on each side, with an elastic ring (india-rubber or bladder).

Thin, very pliable, membranes f. i. skin of a frog, are secured between sieve-like perforated plates of ebonite to prevent bending.

The apparatus is used to demonstrate :

1st, the fact of electric osmosis.

2nd, the specific influence of the membrane ; the rise and fall of the fluid in the cell shows which of the two membranes possesses a greater electric osmotic permeability. On removing one of the partitions, the apparatus becomes an ordinary osmometer.

(Onderzoekingen gedaan in het physiologisch laboratorium der Utrechtsche Hoogeschool. Derde Reeks, II., 1873, p. 365, etc.)

632. Osmometer, illustrating the transpiration of gases through capillary tubes. *Prof. W. F. Barrett.*

This is an apparatus constructed under the direction of Professor Sullivan for illustrating the law of the transpiration of gases. The diaphragm is made of a number of short lengths of capillary tubes.

IV. CONDENSATION AND SOLUTION OF GASES.

633. Adams' Apparatus, for condensing and solidifying carbonic acid. *William Sykes Ward.*

634. Apparatus used in 1857 for Liquefying Ice by Pressure at temperatures below 150° C. *Prof. Mousson, Zurich.*

A small cylindrical recipient, hollowed out of a strong piece of steel, is filled with water containing a movable metallic index. When the water is frozen, the recipient is closed by means of a soft copper cone, subject to the action of a strong screw. The apparatus is then *reversed.* The recipient merges into a long, slightly widening cone of soft copper, on which a short steel rod presses by means of a powerful screw-nut acting on the principal piece, and a double lever a metre in length. If the recipient be opened, after the pressure is removed, the index is found to have been carried over to the other end, as a proof that the ice has been reduced to a liquid state. Soft copper is the only means of closing under excessive pressures.

The experiment can be successfully made at 18° C.

635. Original Model of the Capillary Tube of Messrs. Poncelet and Lestros. *Conservatoire des Arts et Métiers, Paris.*

636. Original Thilorier Apparatus for liquefying carbonic acid, 1857. *Conservatoire des Arts et Métiers, Paris.*

637. Apparatus for illustrating Boyle and Marriotte's law to a class. *Prof. W. F. Barrett.*

The mercury contained in the upper iron reservoir can be admitted to the tube through an aperture closed by a valve that is moved by pulling the string.

The eye is kept level with the air chamber. Equality of pressure with the atmosphere is readily obtained by means of the stopper closing the lower bent tube or air chamber.

638. Compression Pump and Receiver. An apparatus to liquefy and solidify gases.

H. Lloyd, Trinity College, Dublin.

640. Apparatus employed in the researches of Dr. Andrews on the continuity of the gaseous and liquid states of matter, and on the properties of matter at high pressure and varied temperatures. *Dr. Andrews, F.R.S.*

This apparatus consists of two cold-drawn copper tubes of great strength, communicating by horizontal passage, and having massive end-pieces above and below, firmly bolted on with interposed leather washers, so as to be able to resist any pressure. The upper end-pieces are traversed by fine glass tubes, the junction between the glass and metal being made tight by a peculiar system of conical packing. The exposed parts of the glass tubes have a capillary bore, and, if sufficiently fine, will bear a pressure of 500 atmospheres or more without bursting. One of the tubes contains air or hydrogen, and serves as a manometer, the other contains the gas or liquid to be examined. The lower end-pieces carry well hacked steel screws, which produce the pressure by compressing the water with which the apparatus is filled. The temperature of the air or hydrogen in the manometer, and that of the gas or liquid under examination, can be varied at pleasure by enclosing the glass tubes in outer cylinders of glass, or, where accurate readings are required, in rectangular vessels with plate-glass sides. With this apparatus, accurate measurements can be made to 500 atmospheres, or even higher pressure, and with a slight modification, at any temperature which glass will bear without softening.

641. Single Apparatus, adapted to exhibit the properties of gases and liquids under different conditions of pressure and temperature, but without measuring the pressures employed.

Dr. Andrews, F.R.S.

This apparatus is similar in construction to the compound form last described.

641a. Original Apparatus, by Desprey, by the help of which he proved the difference, shown by gases, in relation to the law of Mariotte. *The Faculty of Sciences, Paris.*

641b. Original Apparatus, by Gay Lussac, for ascertaining the elastic force of gases and vapours.

Polytechnic School, Paris.

641c. Apparatus, by M. Dumas, for illustrating the density of vapours. *Conservatoire des Arts et Métiers, Paris.*

642. Sulphurous Acid Tube, to exhibit the flickering striæ which occur from slight changes of pressure near the critical point of temperature. *Dr. Andrews, F.R.S.*

643. Model, constructed by Professor J. Thomson, to illustrate the results of the experiments by which Dr. Andrews first established the continuity of the gaseous and liquid states of matter.
Dr. Andrews, F.R.S.

V. HYDROMETERS.

644. Surface Spring Indicator.
H. Hädicke, Demmin, Pomerania.

The indicator was constructed by the exhibitor, and executed from his drawings by Messrs. Blanche and Co., in Merseburg. The piston has been replaced by a surface spring, and the construction aims—

1. At avoiding the friction of the piston of the indicators hitherto in use.
2. Avoiding the slackness of the piston.
3. Avoiding the points of the diagram of machines of rapid motions produced by the mechanical momentum of the piston.

645. Compensation Salinometer.
H. Hädicke, Demmin, Pomerania.

The compensation salinometer is an areometer especially constructed for measuring the saliferous contents of sea water, or of the water in steam boilers, the readings of which are independent of the temperature of the respective fluids. The dimensions of the same have been so calculated that the increase of the volume of the instrument effected by the expansion of all its constituent materials (*i.e.*, aluminum, or iron and mercury) will avoid the deeper immersion which in the instruments of the ordinary construction would take place in consequence of an increase of the temperature of the fluids.

646. Apparatus for measuring the Density of Liquids.
Professor Dr. Bohn, Aschaffenburg.

647. Apparatus for determining the Vapour Density, on Dr. Frerich's system. *F. Sartorius, Göttingen.*

648. An Oleometer. An instrument for ascertaining the density of oils. *Dring and Fage.*

649. A Small Sykes's Hydrometer. *Dring and Fage.*

650. A Barktrometer. Used by tanners for ascertaining the density of bark liquor. *Dring and Fage.*

The indication of the steam in degrees and true specific gravity at 60 F.; the sliding rule accompanying the instrument enables indications at higher or lower temperature to be reduced to the equivalent at 60 F.

651. A Small Barktrometer. *Dring and Fage.*

The same in principle as the larger one, only not capable of indicating over so wide a range of gravities.

651a. A Tan Tester, for ascertaining the exact quantity of tannic acid in any substance by passing it through a piece of hide.
Thomas Christy and Co.

The solution having been gauged by a tannometer before being tested and after it has passed through the hide, the *difference* gives the exact value of any tannic matter, and a merchant knowing the price of oak bark can calculate the value at once of the substance he has tested.

652. A Salinometer, used on steam vessels to ascertain the amount of salt in the water in the boiler. *Dring and Fage.*

On the stem of the instrument are the words "limit" and "blow." "Limit" indicates the maximum amount of salt in the water that can be used with safety, and "blow" when it is necessary to blow off a portion of the water in the boiler through there being too much salt in solution.

653. An Atkins' Saccharometer. (Obsolete.)
Dring and Fage.

654. A Four-weight Hydrometer on Sykes's principle. (Now disused.) *Dring and Fage.*

The stem is divided into 20 parts, and a part again divided into 2 parts, each of which is equal to one-half per cent. The sliding rule accompanying this instrument gives the equivalents of other hydrometers of the same period. About 1817.

656. Sykes's (Revenue) Hydrometer. For ascertaining the proof-strength of spirits. *Dring and Fage.*

The instrument, used by the Revenue for collecting the duty on spirits, was first established by Act of Parliament in the year 1816; by this Act also proof spirit (which forms the basis of estimation in this instrument, as all strengths are indicated by their relation to this point) received a particular definition as that which weighed twelve-thirteenths of an equal bulk of distilled water at a temperature of 51° Fht. The stem of the instrument is divided into 10 parts, and each part again divided into divisions, which, with the nine weights (each of which is a multiple of the divisions of the stem), enables the instrument to measure all gravities from 67 over proof to just past distilled water at 60 Fht. The tables which accompany this instrument were compiled from the experiments of Gilpin, who carried them out with such accuracy that no error has ever been detected. The range of temperature given is from 30° to 80° Fht. These tables having been found inconvenient for use in hot climates in the year 1851, Messrs. Dring and Fage compiled an extension from 80° to 100°, which meets all requirements for high temperatures.

657. Clark's Export Hydrometer (obsolete). Used for ascertaining the strength of spirits in the various stages of manufacture. *Dring and Fage.*

The instrument used for determining the strength of spirituous liquors prior to the introduction of Sykes's hydrometer. This instrument was the first of its kind established by Act of Parliament, and to which any definite kind of correction for temperature was applied. It is constructed to show the number of gallons of water, plus or minus, necessary to reduce to proof strength a sample of spirits under trial, and was only used for spirits in the various stages of manufacture.

658. Clark's Import Hydrometer (obsolete). Formerly used for ascertaining the strength of spirits imported.

Dring and Fage.

The same in principle and construction as the one for export, only having nine extra or intermediate weights, called per cent. weights. This class of instrument was only used for determining the strength of spirits imported, and was adjusted slightly in favour of the importer.

659. Set of Six Twaddell's Hydrometers. Used for ascertaining the density of solution; principally used in trades for which no special instrument of the kind is constructed.

Dring and Fage.

The divisions on these instruments are so placed as to indicate equal differences of gravity. The specific gravity of a fluid is formed from the indication of this scale by multiplying by 5, cutting off 3 decimal places, and prefixing unity.

655. Specific Gravity Instruments, for testing liquids from 650 to 900 spec. grav. *L. Oertling.*

659a. Fahrenheit's Metal Hydrometer.

The Physical Science Laboratory of the Technological Institute at St. Petersburg (Russia).

The theory of this instrument has been described and illustrated by an example by E. Lenz, Academician, in the "Bulletin physico-mathématique "de l'Académie des Sciences," Vol. XV., 1857.

660. Thermo-Dilatometer, by Baudin, showing the strength of alcohol in 100ths. *M. Baudin, Paris.*

661. Thermo-Dilatometer, by Baudin, showing the alcoholic strength of wines and other liquids.

(The last two instruments are the property of the "Conservatoire des Arts et Métiers.") *M. Baudin, Paris.*

662. Dring and Fage Saccharometer, for ascertaining the density of brewers' worts. *Dring and Fage.*

Used for determining the density (in pounds weight) of a barrel of wort, of 36 imperial gallons, in excess of the same quantity of distilled water at a temperature of 60° Fht. The rule accompanying the instrument shows the weight of the residuum if a barrel of wort were evaporated to dryness; also the amount of proof spirit to be obtained, and the specific gravity.

This instrument was the joint invention of Messrs. Dring and Fage, and perfected by the valuable experiments and calculation of Dr. Hope Coventry and Thomson.

663. Quin's Saccharometer. (Obsolete.)

Dring and Fage.

664. Dring and Fage Still, for ascertaining the original gravity of a wort from a sample of beer. *Dring and Fage.*

Used by the Excise and Customs when making the allowance for drawback on export beer.

664a. Apparatus by Rakowitsch for testing **Alcohols** and **Saccharine Matter** in **Liqueurs ;** likewise for ascertaining the fatness of butter, and for testing water.

R. Nippe, St. Petersburg.

665. Apparatus for determining the Specific Gravity of bodies, inclusive of a thermometer.

Ch. F. Geissler & Son, Berlin.

670. Parabolic Diagram of the relation between tension and volume of the saturated steam.

H. Hädicke, Demmin, Pomerania.

This parabolic tension diagram shows that it is justifiable to replace Mariotte's oder Pambour-Navier's tension-lines of the saturated steam by a parabola. This method gives for the ratio of the mean pressure (p_0) on one side of the piston to the absolute pressure at the commencement (p), and the cut off (ϵ) the elementary formula : $p_0 = p - \frac{1}{6} (1-\epsilon)^2 (4\ p+1)^2$, or $\epsilon = 1 - \frac{\sqrt{6(p-p_0)}}{4\ p+1}$.

(See "Practical Tables and Rules for Steam Engines," by H. Haedicke Kiel, 1871.)

671. Piknometer. *Dr. H. Geissler, Bonn.*

672. Two Sets of Areometers. *Dr. H. Geissler, Bonn.*

673. Manometer for Minute Observations, used by A. de la Rive in all his latest researches concerning the propagation of electricity in rarefied gases.

De la Rive Collection, the property of Messrs. Soret, Perrot, and Sarasin, Geneva.

This instrument, constructed by the Geneva Association for the Construction of Scientific Instruments, consists of two glass tubes dipped in a common mercury trough, of which one is a simple locomotive tube serving as a point of comparison, the other communicating on its top with the quantity of rarefied gas by means of a pipe adjusted in the setting of the apparatus. The pressure, that is, the difference between the two mercury columns, is read by means of a small cathetometer, of which the millimetric graduation is turned towards the tubes and the lamp which lights them both. This graduation is reflected in the telescope by means of a full reflecting prism placed before the objective. Thus the level is at once read, and a micrometrical division placed at the focus of the eye-piece shows the $\frac{1}{25}$ of the millimetre.

673a. Delicate Pressure Gauge.

Dr. K. List, Hagen, Westphalia.

The very light pressure required to produce a current through the stoves can be shown by the delicate pressure gauge (enclosed in a mahogany case), which has a thin diaphragm exactly one square foot in area, and has a light lever and weights to cause it to bear the pressure brought on its surface, so that the whole pressure of the air on one square foot is exactly weighed with ease. As small a pressure as one hundredth of an inch of water can be measured.

673b. Multiplying Manometer, for measuring the force of draught in chimneys, and stoves, as well as for the pressure of gas. *Dr. K. List, Hagen, Westphalia.*

This apparatus was first constructed by the exhibitor in 1862 for the purpose of meeting the desire of several puddling furnace proprietors resident at Hagen, who wished to be able to measure more accurately the draught in their furnaces than was possible with the ordinary manometer, consisting of a curved glass tube, as is mentioned in the description given in the "Zeitschrift des Vereins deutscher Ingenieure," (Journal of the German Society of Engineers) of 1863, vol. vii, p. 493. It consists essentially of a long narrow horizontal and two wider vertical glass tubes, the latter of which are filled to about half their size, and the first up to a long air-bubble, with coloured petroleum. If a suction is effected on one of the vertical tubes, the air-bubble contained in the horizontal tube must, in case the vertical tube should have a diameter n times as large as the horizontal tube, travel a space n^2 times as large as the liquid rises or falls, as the case may be, in the vertical tube; the sensibility therefore, can be increased at pleasure. The space which the index travels is $\frac{n^2}{2}$ times as large as the difference in the respective heights of the liquid in the two vertical columns.

The apparatus having been constructed for some years by the exhibitor himself, the scale indicating in water-millimeters the difference of pressure was prepared by him in the manner described in the Journal of the German Society of Engineers mentioned heretofore. The apparatus has answered well everywhere. It has been recommended for measuring the pressure of gas by authorities such as Schiele in Frankfort-on-Maine and Schilling at Munich.

673c. Level for Manometer. *M. Breguet, Paris.*

673d. Control Manometer, with two-fold safety. *C. D. Gäbler, Hamburg.*

1. The advantage here consists in two independent manometers, acting under quite similar conditions, being combined in one case, whereby not only a greater guarantee of control is obtained, but by the close proximity of the two scales the simultaneous reading of the divisions is facilitated. The upright position of the tubes prevents the collection of impurities out of the water, as the latter flows freely away after use. The instrument may be connected by a simple screw arrangement with the boiler.

673e. Control Manometer, with four-fold safety. *C. D. Gäbler, Hamburg.*

This manometer, consisting of two manometers of the above construction, combined one with the other, offers the greatest possible safety in controlling; because, if only two-fold safety be asked, the one pair of manometers can be put out of action by closing the stopcock, and may thus be used as reserve or control of the manometer thence used. The connexion with the boiler flanche is performed by means of the accompanying two thumb nut-screws.

673f. Control Manometer, showing the inner construction. *C. D. Gäbler, Hamburg.*

Shows the extremely simple construction of the inner mechanism of the manometers described above.

674. Alcoholometer, consisting of two cylinders of ebonite and brass, keyed together. *G. Recknagel, Kaiserslautern.*

The alcoholometer is not liable to break, and answers all requirements of accuracy in reading.

675. Areometer of ebonite and brass, with adjustable cylinder. *G. Recknagel, Kaiserslautern.*

This not being liable to be broken can be used for educational purposes as well as for practical application.

The upper terminal level plate is adapted for placing small weights on it, by means of which the meaning of the dividing lines can be demonstrated. The instrument, moreover, is arranged with a *cylindrical slide*, which can be extended to the double volume of the divided spindle. If the scale is exhausted, the slide is to be pulled out a volume more, and the scale is then again at disposal for use.

The most suitable for instruction and practice is the uniform scale of the Gay Lussac areometer. As, however, there is easily room for four scales, the others can be arranged for direct indication of specific weights, or, like the present models, for alcoholometry.

676. Areometer Case, containing three standard areometer-cylinders, for determining the specific gravity of all kinds of liquids, with indicator scale fused to them. *W. Zorn, Berlin.*

677. Areometer. The indicator scale is not fused into the glass, but fastened only with sealing-wax. *W. Zorn, Berlin.*

Each of these areometer-cases contains three glass spindles, which, loaded at the top in a similar manner to Nicholson's metal spindles, with weights, indicate with the greatest accuracy the specific weight of *all* liquids.

The liquid to be tested must be brought to a temperature of 15° Celsius; if one of the spindles is inserted in the liquid, so many weights must be placed on the glass plate as are required to make the spindle sink as far as the black mark on the milk-white glass line in the neck of the spindle.

The lightest spindle embraces all liquids from 0·650 to 1,000; if this has been used, 0·650 must be added to the weight placed on the spindle. If the medium (1,000) spindle has been employed, 1,000 must be added to the weight, and at the heaviest (1,400) spindle, 1,400 must be added to the weight placed on the same. The sum obtained will give the specific weight of the liquids with an accuracy extending a little over the third decimal.

The proof of the correctness is simple; it is only necessary to have a good pair of scales and some distilled water:

650 weight = spindle 0·650; spindle 0·650 +
350 weight = spindle 1,000; spindle 1,000 +
400 weight = spindle 1,400.

The construction of these areometers is *new*. For many years the exhibitor had constructed similar areometers, consisting, however, of two spindles only, which were very much liked, under the name of Wittstock's areometer, on account of their accuracy; but it was too fragile, owing to the light spindle (because there being but two of them) having to carry too much weight. Moreover, the late Privy Councillor, Dr. Wittstock (apothecary to the Royal Court at Berlin), had devised a peculiar proportionate weight to the same, from which the spindles had derived their name, but which is now no longer in use.

The areometers constructed by the exhibitor, the normal weight of which has been recommended by Mr. Hirsch, apothecary, at Giessen, and which corresponds to the gram scale, have the following advantages, compared with other similar instruments :

They can be easily tested as to their accuracy (as shown before); they will not be affected by the liquids; they can be easily cleaned, and will sink slowly and uniformly in any liquid, and are not surpassed, not even equalled, by most similar instruments, in respect of accuracy.

One of the exhibited areometer-cases contains three spindles, which are perfectly equal in point of accuracy with those in the second case. The milky glass lines at the neck are, however, fastened only with sealing-wax, which, in case of great carelessness, may dissolve, although persons of experience have used these spindles for years without injury; besides, every particle of sealing-wax can be easily supplied as soon as any defect has been noticed. But, in order to avoid this, the milky glass lines on the three spindles in the second case have been melted together with the glass plate.

Besides the weights, there are added to the two cases a cylinder for weighing the liquids, a pincette for placing the weights, and a thermometer for determining the temperature of the liquids, which latter, by reason of its form and the strength of the glass, is at the same time to be used as a stirring rod.

The exactness of the indications of Zorn's spindles affords also the advantage of testing the correctness of other liquid scales, such as Tralles, Baumé, and others made on a scientific basis.

679. Alcohol-meter.

Siemens Brothers and Co., Charlottenburg.

679a. Metallic Alcoholometer, on Tralles's principle.

W. Gloukhoff, St. Petersburg.

The metallic alcoholometer, with additional weights, newly adapted by the Russian Government. This alcoholometer is made on the principle of Sykes's hydrometer, but its scale is adapted to the system of Tralles, legalized in Russia.

VI. MISCELLANEOUS.

680. Apparatus, serving to illustrate the **Mechanical Effect** of the **Expansion** of **Liquids.** *T. A. Snyders, Delft.*

Gun-tubes closed by lead plate 3 millimetres thick, which is maintained by an annular screw-piece. The expansion of the liquid causes a disc of lead to be drawn out with a crack through the hole of the screw-piece.

681. Apparatus, constructed by **Leschot** and **Thury,** to **suppress Friction** by the interposition of a stratum of air.

Geneva Association for Constructing Scientific Instruments.

The apparatus is composed of two plates, superposed, and perfectly adjusted, between which is introduced a pressure of air or gas. The air, spreading from the centre between the two plates, bears upon these a pressure measured by its elastic force and by the extent of the surfaces brought into apparent contact. When this pressure equals or exceeds the weight of the plates acted upon, this is upheld in the air, where it becomes subject to extraordinary mobility. Having no longer any weight, the friction which is proportioned to weight is annulled, and the resistance no longer depends on that property scarcely yet studied, the viscidity of the air.

682. Rotation Apparatus for determining the effect of Atmospheric Resistance on bodies of different shapes, particularly on projectiles. Constructed by Theodor Baumann, junior, Mechanical Engineer, Berlin.

Professor Dr. E. E. Kummer, Berlin.

(See "Abhandl. der Königl. Akademieder Wissenschaften in Berlin, 1875"; "Über die Wirkung des Luftwiderstandes." by E. E. Kummer.

683. Two Apparatuses for measuring the Transpiration of Air at different Temperatures.

Dr. O. E. Meyer, University of Breslau.

(Described in "Poggend Ann., 1873," vol. 148, p. 203.)

684. Apparatus to illustrate to a large audience the fact that the **pressure** exerted by a **curved liquid** film increases with the curvature.

The apparatus consists of a glass tube communicating with two others, each of which is furnished with a stop-cock. Bubbles of different diameters are blown at the ends of the tubes, one stop-cock being closed while the other is open, and then communication with the outer air being cut off, and the cocks both opened, the smaller bubble is seen to diminish and the larger one to increase, thus proving that the air inside the smaller bubble was the more compressed. The tubes are bent, so as to bring their extremities close together, and the experiment can be shown to a large audience by throwing a magnified image of the bubbles on a screen.

685. Apparatus for demonstrating **Leidenfrost's phenomenon** of **drops.** *Dr. J. Hoogewerff, Rotterdam.*

This apparatus was constructed by Mr. Kellenbach, curator of the Batavian Society at Rotterdam, and belonging to the academy of plastic arts and technical sciences at Rotterdam. The apparatus is used as follows: A Grove pile is connected with the instrument, a galvanometer being placed on the conducting wire, and the copper tray or platinum capsule into which the drops of water have been put, are heated by means of a gas lamp. Every time Leidenfrost's experiment is repeated, no current is indicated by the galvanometer, contact having been interrupted by the layer of steam; when on the contrary the water, the surface of which is in contact with the copper wire, comes into immediate contact again with the metallic surface of the tray or capsule, the galvanometer distinctly indicates the current.

686. Apparatus for determining the **Tension** of the **Vapours** of different liquids at the boiling point. *Prof. W. F. Barrett,*

This is a common form of apparatus. The liquids whose tensions are to be measured are inserted in the barometer tubes, and either steam or the vapour of some liquid having a lower boiling point, such as alcohol, is sent through the larger tubes.

686a. Apparatus for illustrating the **Tension** of **Vapours** at or below the freezing point. *Prof. W. F. Barrett.*

687. Diagram of Torricellian Vacuum. 1644.
A. Galletly, Edinburgh.

687a. Independent Bed Plate for **Pneumatic Machines.**
Geneva Association for Constructing Scientific Instruments.

This plate is made entirely of cast-iron, as well as its stand, so as not to become damaged in experiments where mercury is employed.

687b. Sir Humphery Davy's Laboratory Note Book.
Royal Institution of Great Britain.

Davy's record of his decomposition of potash by the voltaic battery, October 19, 1807.

687c. Faraday's Laboratory Note Book.
Royal Institution of Great Britain.

Faraday's record of his condensation and liquefaction of gases, March 19, 1823.

SECTION 6.—SOUND.

WEST GALLERY, UPPER FLOOR, ROOM (Q).

I.—SOURCES.

688. Apparatus used by M. Rijke to cause a tube to emit sounds when wire gauze placed in the interior is heated.

Professor Dr. P. L. Rijke, Leyden.

689. Whistles for producing shrill notes, within and beyond the limits of ordinary audition. *Francis Galton, F.R.S.*

These whistles were designed for testing the limits of the power of men and animals of hearing very shrill notes. The plugs that close the whistles can be screwed up and down, and the length of the whistle, and therefore the number of vibrations per second, can be ascertained by the attached graduations. The whistles are of three forms : (1) a small cylindrical tube, which gives a pure note, but of small power ; (2) a flat, wide and narrow whistle, of which the plug is a broad thin plate of metal ; (3) an instrument which is externally a cylinder of 2½ inches in diameter, but of which the effective part is merely an annulus ; the plug of this is a cylindrical sheet of brass ; it gives a powerful note, but not a very pure one.

690. Brass Tube to sound the constant proper tone of the mouth, characterising the vocal sound.

Professor Donders, Utrecht.

This consists of a brass tube ending in a broad slit, at the other end with an india-rubber tube to be placed on a blower "*souffleur*." (Donders.) The blast, directed by the slit on the borders of the lips, sounds during the time a vocal sound is sung in different tones, the constant proper tone of the mouth characterising the vocal sound. (Compare Donders, Uber die Natur der Vocale, Holl. Beit. zur Nat. u. Heilk. 1846.)

691. Set of Vowel Forks and Resonance Globes.

Frederick Guthrie, F.R.S.

692. Set of Organ Pipes. *Frederick Guthrie, F.R.S.*

693. Set of Tuning Forks. *Frederick Guthrie, F.R.S.*

694. Photograph of a Chemical Harmonica of glass for gas-flames, with eight pipes (major-scale from d^1 to d^2 inclusive), with double regulating cocks, and key-board for playing. With a copy of a few melodies executed on the same for two and three voices.

Professor J. Joseph Oppel, Frankfort-on-the-Maine.

The apparatus itself is, on account of its brittleness, difficult of transport. The glass tubes can be turned by means of metal mountings, and can be displaced in respect of the height of the flames, the largeness of the latter being regulated by small cocks, and the acoustic effect of the major and minor accords (particularly when carefully tuned) are really astonishing.

695. Diapason Tuning Fork. *F. Ernecke, Berlin.*

695a. Diapason arranged for continuous action. *T. Hawksley.*

696. Tube for Singing Flames, according to Schaffgotsch's system. *Albrecht, Tübingen.*

697. Set of Glass Tubes for illustrating singing flames, with paper slider for adjusting the pitch of any tube. *Prof. W. F. Barrett.*

698. Set of Resonant Tubes. *Prof. W. F. Barrett.*

By suddenly and successively withdrawing the stopper, the resonance of the air within the series of tubes will give the notes of the common chord.

699. Apparatus for experiments with singing gas flames. *Yeates & Sons.*

The above, consisting of glass tubes of similar size, with the assistance of a revolving mirror, will illustrate most of the phenomena of interference, harmony, &c.

700. Inferior Limits of Audibility. An apparatus to show the lowest number of vibrations that will produce sound. *Elliott Brothers.*

701. Sir Charles Wheatstone's Resonating Tube. *W. Groves.*

By moving a piston up and down, and thus diminishing or enlarging the resonator, a perfect two-octave scale of aliquot parts may be produced from a spring, which would otherwise sound but one note. The scale may thus be played as rapidly as by the fingers upon a pianoforte. Set the spring in vibration by a twang with the forefinger of the left hand, and draw the piston with the right hand.

701a. Sir Charles Wheatstone's Reciprocating Instrument, for rendering the vibrations of rectilinear wires audible at a distance.

Robert Sabine, 25, Cumberland Terrace, Regent's Park.

704. Set of five Steel Tuning-forks on a new system. *Dr. Stone.*

II.—MEASUREMENT.

705. Revolving Drum, for determining pitch of note.
Prof. Frederick Guthrie, F.R.S.

The styles attached to two vibrating forks mark sinuosities on the blackened surface of the drum when it turns and advances on its screw axis. The pitch of the notes is thus compared.

705a. Apparatus, by M. Regnault, for ascertaining the velocity of sound. *College of France, Paris.*

706. Acoustic Apparatus, for ascertaining the velocity of transmission of sound through water, used in 1826 on the Lake of Geneva at a distance of 13,487 metres, and subsequently in 1841 at a distance of 35,000 metres.
Professor Daniel Colladon, Geneva.

Acoustic apparatus used in 1826 and 1841, during a series of experiments upon the transmission of sound through water, and upon the direct measurement of the velocity of sound in the water of the Lake of Geneva.

Mémoires de l'Académie des Sciences de l'Institut de France, savants étrangers, sciences mathématiques et physiques, vol. 5, 267 and following pages. Comptes-rendus de l'Institut, vol. 13, p. 439, séance 23rd August 1841.

N.B.—With this instrument it is possible in calm weather to hear, at the distance of more than a hundred kilometres, the reverberation of blows struck upon a bell of about half a ton weight immersed in the water, and thus to use it as a submarine telegraph, or for transmitting signals in foggy weather.

707. Apparatus for marking Tuning-fork Vibrations.
Professor L. von Babo, Freiburg, Breisgau.

707a. Original Apparatus, by Duhamel, for registering vibrations. *Polytechnic School, Paris.*

708. Helmholtz' Double Siren.
H. Lloyd, Trinity College, Dublin.

709. Double Siren, such as was employed by Professor Helmholtz in his researches on sound.
Prof. Frederick Guthrie, F.R.S.

710. Siren, of card-board, with four circles of holes, 64, 80, 96, and 128, giving major chord. Made by Yeates and Sons.
Prof. W. F. Barrett.

The above is provided with an air-chest and four keys, so that any or all the circles of holes can be made to sound at pleasure.

711. Siren, an instrument for showing the number of vibrations corresponding to a given note. *Elliott Brothers.*

712. Savart's Toothed Wheels. A set of wheels, of different sizes and numbers of teeth, to produce a succession of notes. *Elliott Brothers.*

713. Sonometer, with sound-post on the principle of the violin. Also adapted for passing the galvanic current through strained wires. *Dr. Stone.*

714. Metronome, invented by Dr. Wollaston. *G. H. Wollaston, Esq.*

715. M. Le Roux's Apparatus, for determining the velocity of sound. *Conservatoire des Arts et Métiers, Paris.*

716. Phonometer. *Prof. Lucae, Berlin.*

The phonometer, "speech-scale," is intended to determine accurately the intensity of speech, that is to say, the pressure of expiration employed in speaking.

The apparatus consists of a short metal tube, one end of which expands in the shape of a funnel to a kind of mouth-piece, whose brim is coated with gutta-percha. At the other end of the tube is attached a contact lever oscillating in an axis, the lower section of which lever is formed by a round aluminium plate, which, when in a state of repose, that is to say, at the vertical position of the contact lever, closes the tube, whilst the upper end of the contact lever, terminating in a point, indicates on a quadrant the oscillations of the pendulum. By any word which is spoken into the mouth-piece, the plate will be pressed outwards according to the pressure of the air employed. A spiral spring attached to the axis has the effect, that by discontinuing speaking the contact lever remains stationary in the maximum of the motion transmitted to it, and its inclination can be read on the quadrant. The practical use of the instrument in the first instance is, to determine when speaking in a loud or a low voice the relative intensity of one and the same word, or, rather, the preponderating sound prominent in the word uttered, and imparting to it the greatest colour. This object the apparatus perfectly accomplishes, since the force of the utterance is proportional to the density of the air effected in the tube. The apparatus consequently admits, among other things, of a more exact test of hearing with persons slow of hearing than has been the case hitherto with ordinary speaking.

716a. Phonoptometre, by M. Lissajous. *M. J. Duboscq, Paris.*

716b. Experimental Windchests, for measuring the effect of heat on reeds. *Dr. Stone.*

III.—ANALYSIS AND SYNTHESIS.

717. A series of Chladni's Figures. *Prof. Frederick Guthrie, F.R.S.*

Sand being scattered on a square brass plate, clamped in the middle and horizontal, the plate is bowed at various points of its edge, while various other points are touched with the finger. The sand is accumulated in the lines of least motion or nodal lines. Gummed paper is then pressed upon the figures so formed.

718. Five Wire Figures for representing **Lissajous' Designs.** *Professor Buys-Ballot, Utrecht.*

On a horizontal wooden rod are placed five figures of wire, so bent that their shadows or lens images form the designs of Lissajous. Each interval has its own wire figure, and the changes produced by various phase-differences are shown by turning the figures round their vertical axes.

719. Wooden Board for constructing **Lissajous' Figures.** *Professor Buys-Ballot, Utrecht.*

The instrument consists of a white-painted wooden board, on which a circle is traced. Horizontal and vertical lines cut the circle in points corresponding to the angles of a regular inscribed icosagon. At the intersection of each pair of lines a hole is made in the board for fixing pins; that for showing the figure can be joined by a thread. Along one of the horizontal and vertical sides of the board two rods can be fixed, provided with ciphers corresponding with the horizontal and vertical lines. Each of these lines may be figured to represent the phase of a vibrating particle either by sound or light for each twentieth part of a vertical and horizontal (two rectangular) direction.

For instance, the figure exhibited by the interference of two notes of the same pitch is designed in the following manner:—The horizontal rod indicates the vertical chords on which the particle is at a supposed moment by a horizontal vibration, then the perpendicular rod indicates in the same manner the horizontal on which it would be at the same moment by a vertical vibration. By fixing pins at the intersections of those chords indicated by the same ciphers, and joining them by a thread, you have the desired figure originated by both motions.

If the oscillations differ in phase, you find another rod not beginning with the same cipher, but with another differing as many twentieth parts of the oscillation as you like.

If the two interfering notes are not of the same pitch, but one figure is the octave of the other, you take for the higher note a difference of phase double as great as for the other, and so on.

719a. Tonophant, a simple arrangement for showing **Lissajous' Figures.** *Professor W. F. Barrett.*

720. Melde's Universal Kaleidophon.

Ferdinand Süss, Marburg.

(*See* Poggendorff's Annalen, vol. 114, p. 117.)

This apparatus is too well known already to require in this place a more detailed description as regards its capabilities. It will therefore be necessary to give only a short explanation of the reading indications on the Lamellæ, and to refer, as to all specialities respecting this apparatus, to Prof. Melde's publications. Poggendorff's Annalen, Vol. CXIV., page 117, " Lehre von den Schwingungs-Curven," by Dr. Franz Melde, p. 25.

The great Lamella has on each side a line as a mark, and on its upper end the figures I. and II. ; the smaller Lamellæ have the same figures I. and II., and on each side three lines.

If the great Lamella is placed upon the mark of side I., and the small Lamella on the line of side I., with the indication $\frac{1}{4}$, then the vibrations of both Lamellae to each other are as 1 : 4. The indications of side II. naturally correspond to the mark of side II. on the great Lamella.

The Lamella with the little mirror is used when the curves are to be shown to a whole auditory, for which purpose the apparatus ought to be so placed that the rays of the sun, or electric light, fall on the mirror, so that from this the reflection is thrown either on the ceiling or on the wall of the room.

The round bars serve for the production of oscillating curves of two elliptical vibration movements.

Finally, it is to be observed that the apparatus may be used equally well for fixing the vibration curves, for which purpose a phonautograph is employed, the cylinder of which is covered with a paper, *as smooth as possible*, on which soot is laid, but not too thickly.

A small piece of the top of a feather fastened with wax upon one of the smaller Lamellae will be sufficient to describe the curves. In this case, the oscillating surfaces ought to be parallel.

721. Atlas, belonging to the same, illustrative of the theory of oscillating curves, by Dr. F. Melde.

Ferdinand Süss, Marburg.

722. Melde's Tuning-fork Apparatus for producing stationary waves on a thread.

(*See* Poggendorff's Annalen, vol. 109, p. 193; and vol. 111, p. 513.) *Ferdinand Süss, Marburg.*

In Poggendorff's Annalen, Vol. CIX, p. 193, and Vol. CXI. p. 513, this apparatus is described more in detail, as well as several experiments which were made with the same, and likewise the theory of the oscillation curves, ("Lehre von den Schwingungscurven") by Dr. Franz Melde, p. 94.

By means of a little sliding rod (a little glass stick) which is screwed into one of the prongs of the fork, and rubbed with wet fingers, the tuning-fork is brought into a state of vibration. (The little glass stick, owing to its fragility, must be inserted reversely into the wooden frame, when not used, so that only the brass-neck of it is visible. On the lower part of the tuning-fork there is a tunable pin, which takes up one end of the thread, and which at the same time serves for stretching the thread. From this point the thread passes through the small neck of the other prong of the fork to the clamp, which can be moved forwards and backwards on the bar, which is about a meter long, and thus allows up to this limit any length of the thread to be fastened. In order to read the length of the thread, there is on one of the narrow sides of the bar a division indicating half centimeters.

The tuning-fork can be turned about its vertical axis in such a way that its oscillation surface falls in a parallel line with the longitudinal direction of the thread, as well as perpendicular to this, or in any other selected angle.

The bar can be turned about a horizontal axis, and arrested in any desired position by means of the nut of a winged screw fixed at the back, so that the thread can form any desired angle with the longitudinal axis of the tuning-fork.

It requires but little practice to effect such a tension of the thread that the required number of waves always appears.

723. Melde's Apparatus for the Combination of Two Thread-vibrations.

(*See* Melde's Lehre von den Schwingungs-curven, p. 99.)

Ferdinand Süss, Marburg.

723a. Melde's Apparatus for the production of **Oscillating Curves** of two **Rectilinear Thread Vibrations** on a **Strained Thread.**

The apparatus consists of two principal parts, one of which is a Lamella, oscillating vertically, fastened on a pedestal, and which is set in oscillating motion by an electro-magnet. The Lamella itself forms the interference.

The other part consists also of a Lamella, which is brought into vibrating motion by an electro-magnet, and the vibration surface of which can be placed at any desired angle to that of the first Lamella.

In order to put the apparatus in motion for experiments both parts must be firmly fastened with vice pins, either to a long, or on two separate solid tables, at such a distance (about 8–12 feet) from each other that the thread when strained measures 3 to 3·5 meters in length. (The thread can, of course, be shortened at pleasure, as well as be replaced by one a few meters longer; but for college experiments the length stated appeared to be most practical.) The thread is fastened to Lamella I., and passed through the hole in Lamella II. towards the swivel by which the correct tension is effected.

The white points on the (red) thread serve for facilitating the better observation of the curves, and, in order to render them more prominent, the black screen is placed behind the oscillating thread. The screen has on one side small holes, which are hinged in the hooks of the frame of Lamella I.; when the screen is expanded, the foot of it is screwed firmly by a vice-pin to the opposite table.

Two (large-sized) chrome elements, the strength of which may be easily regulated, will be best to do service as electro-motors. In the present case two chrome elements were employed, each with two carbon plates, and a zinc plate, of 18 cm. in height, and 6 cm. in width, joined together one behind the other.

When newly charged, it was only necessary to dip the zinc plate from 1 to 1·5 cm. into the acid, in order to obtain the required force of the electric current. Both elements and the wire spirals of both magnets are, of course, united to form *one* current circle. As already observed, Lamella I. serves at the same time as interference, for which purpose an attachment screw is fixed at the reverse end of the same, which is intended to take up the conduct wire leading to the battery. In the attachment screw, which is in connexion with the mercury bowl, a wire is fastened, which is to be connected with the first attachment screw of the wire spirals, if the numbers of the vibrations of the two Lamellae are to be in proportion as 1:1 *a* 1:2 (accord, octave). If Lamella II. is to perform three or four vibrations in the same time in which Lamella I. makes only one vibration, then only one wire spindle of Lamella I. is set in motion by fastening the wire coming from the mercury bowl in the centre attachment screw. The current must always be so powerful that the interference, whose rough displacement is effected by raising and lowering the platinum pin, and the more minute displacement by turning the mercury bowl, can be so placed, that the shutting off of the current is effected as quickly as possible, as hereupon the purity of the figures chiefly depends.

The intensity of the vibrations on Lamella I. is regulated by raising and lowering the electro-magnet, which is kept in its position by the nut of a winged screw, and on Lamella II. by screwing in and out the iron coves, and by the shifting the whole magnet.

With a powerful current the vibrations will be most regular when the magnet is entirely moved back, and the coves are screwed so closely to the Lamella that the contact just ceases.

Lamella I. has only one mark on which it always remains accurately adjusted. If it is required that it should oscillate uniformly with Lamella II. the latter is moved to the back, marked with the annotation $\frac{1 \;\; a \;\; 1}{1 \quad 2}$ and upon the spot marked with × the weight is placed with the annotation $\frac{1}{1}$. If the weight is removed further from Lamella II. the oscillations of the two Lamellae are as 1: 2. If Lamella II. is moved to the mark indicated by $\frac{1 \;\; a \;\; 1}{3 \quad 4}$ the oscillations of both Lamellæ are as 1:3 (S fifth of the octave)

By placing the weight with the annotation $\frac{1}{4}$ upon the spct indicated with × on Lamella I. the oscillations are as 1 : 4 (double octaves).

The two smaller weights of different size serve for the more exact regulation in case great changes in the temperature, or simultaneous oscillation of either one or the other of the tables, should be of injurious influence.

Lamella II., as has been observed at the commencement, can be turned about an horizontal axis, so that its vibrations can be adjusted either rectangularly, parallel, or in any angle whatever to Lamella I. In case it is necessary to ease and screw fast the hexagonal nut, the key is added for the purpose. The small key is for unscrewing and fastening the screws which fix the Lamella.

724. Melde's Wave Apparatus, for showing the production of Chladni's figures of sound, according to the theory of Wheatstone.

(*See* Poggendorff's Annalen, Jubelband, p. 101, and the accompanying description.) *Ferdinand Süss, Marburg.*

This apparatus has been more particularly described by Professor Melde, in Poggendorff's Annalen, Jubelband, page 101.

The present specimen is distinguished by several differences from that described in the above-mentioned work, so that the manipulation is considerably facilitated, but before entering into this, it must be mentioned that in the construction of this apparatus it was kept in view that two systems of waves of equal length and equal intensity pass swiftly through a square plate.

The upper system of waves is formed of 33 rows of 17 netting sticks each, which together make two wave lengths. The saddle upon which the netting sticks are placed corresponds to a length of 1·5 of wave lengths; it has on two sides (above and below) wave-systems, which in so far differ from one another, as the one is like a system of two mountains with one valley in the middle, and the other like two valleys intersected by a mountain. On the longitudinal sides of this saddle rectangular zinc plates have been screwed on, which are provided with divisions for adjusting the desired phases.

O denotes the centre position (middle between mountain and valley). The lines marked on the black board correspond to the waves formed by the netting sticks. The longitudinal line serves as index upon which the lines of the saddle are indicated.

When the saddle has been adjusted in the desired position, the board is lifted by the handles fastened on the sides—as far as possible perpendicularly—so high, that the wires running parallel under the board catch into the hooks, and so prevent the board from descending..

In order to let the board and the saddle down again, a slight pressure with the thumb on the pegs protruding from the board next to the handles, while holding the handles themselves firmly in their position, will be sufficient to prevent the too rapid, or sideways sliding down of the board.

Finally, it is to be observed, that this apparatus can also very well replace Eisenrohr's Interference Apparatus in so far as two waves will be sufficient; it would only be necessary to add a number of bars, or if entire surfaces are desired, some saddles, the waves of which are of different and certain lengths.

Great care is required by placing the one part of the apparatus upon the other.

725. Wave Disc, by Professor J. Müller.

T. W. Albert, Frankfort-on-the-Maine.

1. The wave-disc by *Prof. Dr. Joh. Müller*, in Freiburg (Breisgau), is an adaptation of the well-known stereoscopic disc (Phenakistoscope, or Wunder-

scheihe), for demonstrating the wave undulation. The eight drawings are for the purpose of illustrating the water, rope, sound, and air waves, in covered as well as in open pipes.

See "Lehrbuch der Physik," VII. Edit. Vol. I., § 155).

726. Telephon, on Reis' system, for the reproduction of sounds by galvanism.

J. Wilhelm Albert, Frankfort-on-the-Maine.

2. The telephon is based on the experiments of Wertheim and others regarding galvanic sounds. *Philipp Reis*, at Friedrichsdorf, made use of these with a view of reproducing by means of galvanic action the musical sounds produced by singing (or by pipes, &c. played upon), by employing an elastic membrane and an interference apparatus constructed by him.

(*See* Jahresbericht des physikalischen Vereins zu Frankfurt a Main. Jahrgang 1860–61; also, "Müller's Lehrbuch der Physik, VII. edit. Vol. II., § 135.

727. Crank Apparatus, for showing the production of progressive (water, &c.) waves.

Prof. J. Joseph Oppel, Frankfort-on-the-Maine.

The rotating liquid molecules are represented by white wooden balls on a black background, and are all put into motion by a crank attached at the back.

The whole shows two wave lengths.

728. Cylinder Apparatus, for showing directly and comparatively progressive and stationary waves of sound, and respectively the essential difference between both.

Professor J. Joseph Oppel, Frankfort-on-the-Maine.

Contains 1½ corresponding wave lengths on both cylinders. Other drawings likewise, for example, with different wave lengths (for illustrating the musical intervals, &c.), can be mounted on the cylinders, which are of a somewhat conical shape.

729. Two Wave Discs of paste-board for stroboscopic illustration of a progressive and a stationary (water) wave.

Professor J. Joseph Oppel, Frankfort-on-the-Maine.

Would be best fastened to a rotation apparatus such as are used for colour spindles, &c., and placed in front of a mirror. All waves, with the exception of a horizontal one, should be covered by a black screen.

730. Brass Tube, with Gas-burner, for Intonation. (Compare Poggendorff's Annalen, vol. 129, 1866.)

Albrecht, Tübingen.

731. Rotating Mirror, movable towards all sides.

Albrecht, Tübingen.

This mirror has not yet been described, but several specimens have already been executed by Mr. Albrecht. That position of the mirror in which its

normal forms a moderate angle with the rotatory axis, is peculiarly adapted to change the reflected image of the sonorous flame into a beautiful elliptical crown.

731a. Barlow's Logograph, an instrument for recording pneumatic effects of speech, being questions to consonants, as well as records. *W. H. Barlow, F.R.S.*

731b. Apparatus for Synthesis of Vowel Sounds. *Prof. Clifton, F.R.S.*

732. Apparatus for the projection on the screen of the curves produced by the combination of rectangular vibrations. *Yeates & Sons.*

IV.—INTERFERENCE.

733. Apparatus for demonstrating, by the aid of flames, the interference of two musical sounds.

The Director of the Physical Laboratory of the University of Groningen.

The apparatus consists of two curved movable cross tubes, narrowed at one end; their narrow openings, being near each other, are tightly fixed in a longer tube, also ending in a narrow opening; this is placed close to a strong flame, and also a very small flame, which can be seen in a rotating mirror. A little movable burner for this small flame is attached to the apparatus. When a sound-wave proceeds from the opening of the instrument, the strong flame diminishes abruptly in length and begins to roar, while the small flame rapidly vibrates, its motion being visible in the rotating mirror. The open ends of the two curved tubes can be placed before the mouths of two unisonant organ pipes, or above two different segments of a vibrating plate. When only one of the pipes is sounded, the flames show the vibrations, but, when both pipes are sounded, there is no agitation of the flames, the two sound-waves counteracting each other. When the two openings are above segments of the plate, which are in the same phase of vibration, the flame is agitated, but, when they are above segments in the opposite phase, the flame remains at rest.

734. Apparatus, of simple character, for demonstrating by the aid of flames the interference of two musical sounds.

The Director of the Physical Laboratory of the University of Groningen.

This apparatus is designed for the same purpose as that last described, but is of more simple construction.

735. Quincke's Interference Tube, to demonstrate by the action of a flame the diminution and increase of sound by interference.

The Director of the Physical Laboratory of the University of Groningen.

This apparatus is furnished with a supplementary brass tube having a narrow opening. It can be used with the same flames as those provided for the instruments last described.

735a. Interference Apparatus, by Jamin. *M. J. Duboscq, Paris.*

735b. Interference Apparatus. *Professor W. F. Barrett.*

V.—ABSORPTION, REFLECTION, AND REFRACTION.

736. Apparatus for showing Approach caused by Vibration. *Frederick Guthrie, F.R.S.*

A suspended card or mass of cotton wool, or an air ball floating in water, approaches a resonant fork ; and the latter, when free to move, is also urged towards neighbouring matter.

737. Apparatus for showing the Expansion of Gases by Sound. *Frederick Guthrie, F.R.S.*

One prong of a tuning fork is enclosed, air-tight, in a glass tube provided with a capillary exit tube, in which water stands at a certain height. On bowing the free prong of the fork the water level is seen to fall about a quarter of an inch.

738. Apparatus for the Reflection of Sound by heated air and vapours. *Professor Tyndall, F.R.S.*

Sound of high pitch from a vibrating reed is passed through a long rectangular chamber, and caused to agitate a sensitive flame. Air, saturated with the vapour of a volatile liquid, is gently driven through six narrow openings into the chamber, at right angles to the direction of the sound. The atmosphere within the chamber is thus immediately rendered heterogeneous, and the sound waves being reflected, the agitated flame is rapidly stilled. The removal of the heterogeneous medium instantly restores the flame to its former agitation.

For the action of heated air, the rectangular chamber is turned upside down upon its support, and the heated air from six gas jets allowed to stream in through six narrow openings across the sound waves. The air thus rendered heterogeneous has the effect of immediately rendering the sensitive flame quiescent.—Phil. Trans., 1874.

739. Diagrams and Apparatus illustrating the reflection and refraction of sound-bearing waves, as exhibited to a class by means of a sensitive flame. *Prof. W. F. Barrett, Dublin.*

The arrangement shows a suitable source of sound, a good form of gas pillar for yielding a tranquil flow of gas to the burner, and the best shape and size of steatite burner for the flame, together with a useful form of gas-holder for giving steady pressure of gas larger than that usually given by the street mains.

VI.—RESONATORS.

740. Resonator of adjustable pitch. *Lord Rayleigh.*

Resonator, whose pitch can be rapidly adjusted to the various notes of a harmonic scale—A^6, a^6, e^6, a^{16}, c^{11}. The smallest hole is made first and adjusted until the resonator responds a^6. The second hole is then made and

adjusted, until, *with both holes open*, the note is e^6. Similarly with three holes the note is a^{16}, and with four holes c^{11}. When the note A^6 is sounded on the piano or harmonium, and the resonator is suitably fingered, the various overtones are heard with great distinctness, and the phenomenon is more marked than usual in consequence of the contrast afforded by the rapid transition.

740a. Sonorous Tubes, by Dulong.

Polytechnic School, Paris.

741. Six Resonators of glazed card-board, for the sounds: c' (256 vibrations), e' (320 vibrations), g' (387 vibrations), c'' (512 vibrations), e'' (640 vibrations), g'' (768 vibrations).

Gustav Schubring, Erfurt.

VII.—MUSICAL INSTRUMENTS.

742. Enharmonic Harmonium, with generalised key-board; 84 keys in each octave; compass, $4\frac{1}{2}$ octaves.

R. H. M. Bosanquet.

This instrument is tuned according to the division of the octave into 53 equal intervals, a system sensibly identical with a system of perfect fifths.

References.—Proceedings Royal Soc. XXIII. 390.
Philosophical Magazine, XLVIII. 507, L. 164.
Proceedings of the Musical Association, 1874–5.
Novello's Dictionary of Musical Terms, Article Temperament.
Ellis's Helmholtz, pp. 692–699.

742a. General Thompson's Enharmonic Organ. Built by Messrs. Robson, London, 1856. *John Curwen.*

It is an improvement upon a similar instrument he exhibited in Hyde Park, in 1851, which also was an improvement on the first organ built for him in 1834. It is capable of being played in 21 keys, with their minors of the same tonic. The organ is fully described in General Thompson's pamphlet, "The principles and practice of just intonation with a view to the abolition of temperament." Effingham Wilson, Royal Exchange. On the middle finger-board the keys of C, G, D, A, E, B, with their minors, can be played perfectly; on the lowest finger-board there can be played, besides the keys of C and G, those of F, B♭, acute E♭, acute A♭, and D♭. The fingering is mainly the same as in other instruments. The red shows the principal key tone of the board. The black shows the fourth and sixth of that scale, as well as the grave second, with which they make a true chord. The white shows the fifth and seventh of the scale, as well as the acute second of the same scale, with which they accord truly. The small oblong quarrils and the flutals (finger keys of a flute) are always a komma shriller or deeper than the digital in which they are embedded. The buttons are always a diatonic semitone deeper or shriller than the adjacent digital. The serrated edges are for the blind.

742b. Harmonium, with double key-board.

M. Guéroult, Paris.

This instrument, of which the two key-boards are tuned in fifths, has a *comma* at $\frac{81}{80}$ interval one from the other, which serves to verify the theories of musicians and natural philosophers upon the melodic or harmonic gamut.

742c. Harmonium with German silver reeds, for diminishing to the utmost changes of pitch due to alterations of temperature.
Dr. Stone.

743. Patent Double Trumpet, called Bi-Clairon.
Franz Hirschberg, Breslau.

The double trumpet (Bi-Clairon), constructed by the exhibitor, is described by him as an equally interesting and practical invention. As the instrument consists of two bell-mouths of different measure and construction, into which the air can be admitted or from which excluded at pleasure through the solitary valve, it has been rendered possible to produce by the same two kinds of sounds, which, according to their sonorous colour, are now equal to the bugle horn, now to the piston (or, also, to the cornet and the trumpet). The instrument is particularly adapted for being used in concerts, inasmuch as by the different sonorous colours more, " light and shade," consequently more variation, is imparted to the execution, and, therefore, no band of musicians should be without it. In a weak orchestral band, in which both bugle horn and piston (respectively cornet and trumpet) are not always represented, this instrument supplies the place of both. Its pitch is high C with B, and A low, and is so constructed that the smaller bell-mouth can be screwed off, in which case the instrument can be used as a common bugle horn (or cornet).

744. Model of the Action of Grand Pianofortes.
Messrs. Erard.

745. Molineux's Patent Self-acting Escapement and Check Repeater Action for upright Pianofortes. It combines extreme simplicity, a firm and elastic touch, with freedom from friction and great durability. *Thomas Molineux.*

746. The first of the now generally adopted **obliquely strung upright Pianofortes,** patented to Robert Wornum, of the firm of Wilkinson & Wornum, in 1811.
Messrs. Wornum & Sons.

The large factory in Oxford Street, in which this instrument was made, is shown by an engraving within the lid. This factory was burnt down in October 1812, and the partnership was then dissolved. In the following year Robert Wornum made the first successful " Cottage " pianoforte, with *vertical* stringing, to which he gave the name of " The Harmonic Pianoforte." He accomplished this by discarding entirely the use of brass wires, and adopting the closely-spun copper-covered strings in their stead.

747. A Model of the Elastic Tie Action of the Piccolo Pianoforte, patented by Robert Wornum in 1826.
Messrs. Wornum & Sons.

The mechanism of this pianoforte is still very generally adopted in France and Germany, as well as in England.

748. A Model of Robert Wornum's method of returning the hammer, in his **down-striking Action** for Horizontal Grand and Square Pianofortes, patented in 1842.

Messrs. Wornum & Sons.

This action greatly economises the cost of manufacture. The usual actions are up-striking.

749. A Model of Alfred Nicholson Wornum's new **Patent Action** for Grand Pianofortes (1875), in which the heads of the hammers are reversed, and now face the wrest plank.

Messrs. Wornum & Sons.

By this invention longer strings may be used, relatively to the external dimensions, than in an instrument of the ordinary construction.

750. Model of the action of **Ancient Great Hydraulic Organ,** from Mr. Chappell's description of the instrument.

Dr. Stone.

751. Marimba or Balafo, from South-eastern Africa. Modern. Given by Captain J. Stuart.

South Kensington Museum.

The instrument has twelve slabs of a sonorous wood, beneath which are fastened, by means of a dark-coloured cement, twelve gourds, to increase the sound. In each gourd are two holes, one of which is at the top, and the other at the side. The latter is covered with a delicate film, to promote the sonorousness. Several African travellers have noticed this curious acoustic contrivance. Du Chaillu says that the film consists of the skin of a spider; Livingstone mentions spiders' web being applied to instruments of this kind used by certain native tribes in Southern Africa. The marimba is a favourite instrument of the negroes as well as of the Kafirs.

752. Glass Harmonica. Modern. Made by E. Pohl, in Bohemia. *South Kensington Museum.*

The glass harmonica consists of a series of glass bells, which are affixed in regular order to an iron spindle lying horizontally in a case, and which by simple machinery are set in motion by the feet. The sound is produced by the performer moistening his fingers and pressing them on the bells while these are rotating.

753. Sol-Fa Harmonicon, invented by Miss Glover. Intended as an assistance in learning singing, and the theory of music. *South Kensington Museum.*

754. Organ Pipes, a selection in illustration of their manufacture, showing the middle C pipe of each stop. *H. Speechly.*

755. Chromatic Harmonium, peculiarly constructed keyboard, "showing the twenty-four progressions. The common method is seen at the back of the instrument in connexion with the keys." *Mrs. Read.*

756. Chromatic Pianoforte, peculiarly constructed keyboard, in which the keys are distinguished by different colours. Intended to facilitate the playing in the different major and minor keys. *Mrs. Read.*

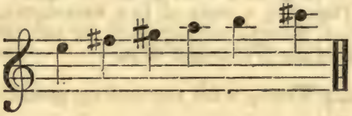
757. Models of several **Ancient Egyptian Pipes,** the originals of which are in the Egyptian Museum at Turin or in the British Museum. Those from Turin are copied in brass, and those from the British Museum in cane.

W. Chappell, F.S.A.

The original pipes were found in Egyptian tombs, some examples being as old as the fourth or fifth dynasty of Egypt. They were played upon by means of a cut or split piece of reed or of straw inserted in the end, as was usual with ancient shepherds' pipes, and much in the manner of the modern hautboy or bagpipe reeds. Parts of the ancient reed or straw remain within one of the pipes in the British Museum, and in another at Turin. Usually a fresh long piece of reed or straw was laid in the tomb by the side of the pipe, and it may be assumed that the object was to supply the dead man with a stock of those perishable inciters of tone in order to play upon his pipe when he awoke. Examples of the straws or reeds so deposited are included in the Museum at Leyden and in the British Museum.

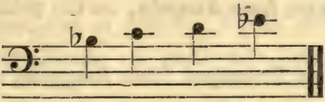
The pipes selected for copying were those which varied in length and in the number of finger holes, so as to obtain varieties of pitch, and varieties of the prehistoric scales. Through the kind assistance of Dr. W. H. Stone, himself an accomplished player upon reed instruments, the following have been ascertained.

1. Pipe from Turin $14\frac{1}{8}$ inches long, with six finger holes. Scale—



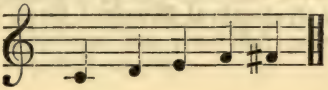
This is the scale of E major, but only extending to six notes. It lacks the addition of D ♯ and E to complete the octave. The fundamental note, or tone of the whole pipe, was not obtained.

2. The longest pipe from Turin, $23\frac{3}{8}$ inches, but with only three holes. The scale is—

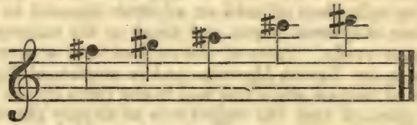


This forms a Diatessarōn, or Fourth from B-flat to E-flat, therefore one note below our C D E F in pitch. In order to obtain the notes from this pipe, it was found necessary to lower the reed into the pipe, as in the drone of a bagpipe. It extends three inches down the tube.

3. A pipe in the British Museum, copied in cane. It has four holes, and is $8\frac{3}{4}$ inches in length. The scale is a Diatessarōn or Fourth, exactly one note above the last, but with an F sharp added to it at the top. Possibly this F sharp may have been intended for a G to make a Fifth.



4. Also from the British Museum, copied in cane. It has four finger holes, and the entire length is $10\frac{1}{8}$ inches. This pipe has a hole bored through it near the mouth end. It would have been absolutely impossible to produce sound from the pipe if this hole had been left open. It may therefore be assumed that it was once covered with thin bladder, such as that of a fish. The intention of placing bladder there would have been to give a tremulousness to the tone of the pipes so as to assimilate it to the human voice. The old English pipe called the Recorder, referred to by Shakespeare in Hamlet, and in A Midsummer Night's Dream, differed in no other respect than that one from the English flute, both being blown at the end. It is curious to find that such an appreciation of the difference of tone that might be produced has been anticipated by the ancient Egyptians. A film of gutta percha is now tied over the hole. The scale is—



This is a peculiar scale, a pentaphōnic major scale, such as is popularly entitled the Scotch scale. It is suitable for playing tunes as upon the black keys of the pianoforte.

It is remarkable that no one of these pipes gives any indication of a minor key, and they seem therefore to be older than the introduction of the minor scale, inherited by us from the Greeks, by the junction of two tetrachords. For this an astronomical or theological reason is assigned, that, as there were but seven planets (according to ancient supposition), and seven days in the week, or quarter of the lunar month, &c., so there should be but seven notes in a musical octave. Therefore a scale of two tetrachords, each of four notes, was reduced to seven, through uniting them by one note common to both. Hence the intervals of our B C D E F G A.

757a. Indian Vina, with resonating gourds.
W. Chappell, Esq.

757b. Patent Comma Trumpet, producing approximately correct intonation, by means of a valve, which raises the pitch the interval of a comma. *Mr. Bassett.*

757c. Marimba from **Angola,** on the principle of the musical box. *Mr. Bassett.*

757d. Wooden Trumpet from **Angola,** made from the root of a tree. *Mr. Bassett.*

757e. Violin, fitted with tension bars. *Dr. Stone.*

757f. Double Bass, with heavily covered fourth string, going down to C C C. *Dr. Stone.*

759. Savart Violin.
Conservatoire des Arts et Métiers, Paris.

759a. A new Orchestral Musical Bass Instrument, with concertina fingering, full tone, and expressive for part and solo performance. *Sir F. Pichler.*

759b. Acoustical Instrument, illustrating Harmony and Discord. *Sir F. Pichler.*

759c. Violin fitted with Tension Bars. *Dr. Stone.*

759d. Viol d'amore, illustrating the principle of consonating springs. *Dr. Stone.*

VIII.—SPECIAL COLLECTIONS.

Detailed List of Instruments manufactured by M. Lancelot of Paris.

Exhibited by Auguste Bel & Co., London.

760. Eight Pieces of Wood, giving a scale.

761. Mouth of a Flute Pipe, showing the inside of the air-chamber.

762. Wertheim's Apparatus.

763. Pipe with glass side, and membrane.

764. Pipe carrying a slide, enabling holes of different sizes and shapes to be opened in the same situation.

765. Four Pipes, all containing the same mass of air, one cylindrical, one cubical, one tetrahedral, one spherical.

766. Three Pipes containing the same mass of air, one prismatic, one in the shape of a right cone, one in that of an inverted cone.

767. Mons. Bourbouze's Pipe with glass side, bearing three membranes, with mirror, one placed at the node of the first sound, the two others at the two nodes of the second sound.

768. Six Plates, five of different woods, one of brass.

769. Two Flat Rods of brass for transverse vibrations. Support for fixing these.

770. Sonometer on Mons. Barbereau's principle.

771. Circular Membranes, with varied tensions.

772. Two Tuning Forks on resonance box, to give four beats a second.

773. Two Tuning Forks, mounted between the poles of electromagnets, with contact-breaker.

774. Duhamel's Vibroscope.

775. Apparatus for transmission of vibrations through liquids.

776. Instrument for showing the quality of vowel-sounds.

Various Scientific Instruments illustrating the Phenomena of Sound, invented and made by the late John Henry Griesbach.

777. A Monochord, with apparatus for printing and registering the vibrations of strings, with a view to ascertaining the number of vibrations per second.

778. A Phonometer, by means of which the equally tempered 12 fixed sounds in the octave may be produced.

779. A Monochord, giving the positions of the Nodal Points in vibrating strings.

780. A Monochord, which affords the means of measuring the 200th part of an inch, with a view to ascertaining the number of vibrations given by that length of string.

781. An Apparatus for producing musical sounds, mainly consisting of notched wheels of different diameters, which, being set in motion at a given pace, and duly prepared pieces of cardboard brought in contact with their teeth, produce the notes of the common chord; the number of notches in the wheels corresponding with that of the vibrations required to produce those notes.

782. An Apparatus for showing the relative positions of the vibrations of two strings or tubes under the operation of altering the ratios; the strings first tuned to coincidence as unisons, the ratios then altered by lowering the pitch of one of the strings, as from 81 to 80, 82 to 80, or any other numbers within the scale of the apparatus.

783. A Set of Flue Pipes, with bellows attached, some of which have too high sounds to be heard singly, but which together give the resultant tone.

784. A large Set of Coloured Diagrams for illustrating lectures on sound.

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785. Collection of Acoustic Apparatus.

George Appuun and Sons, Hanau.

785a. Three Acoustic Wind-Chest Tables. These three tables are required for placing all the following apparatus:—
George Appunn and Sons.

1. *An Overtone Apparatus,* consisting of 24 lingual tones, the first 64 part tones of the fundamental or key tone (primary sound) $C^{-2} = 22$ vibrations in a second with reed pipes.

2. *The same Apparatus,* consisting of 32 lingual tones, the 32 part tones of the fundamental tone $C^{-2} = 32$ vibrations.

On the overtone apparatus there result quite plainly the corresponding difference-tones of all phases that may be chosen at pleasure; also, up to a certain point, the corresponding resultant tones. By means of this overtone apparatus not only the waves and the quality of the sound can be demonstrated, but likewise the different degrees of harmony of the various musical proportions (rhythm), and of poly-accords in different keys and transpositions. The latter, in particular, in combination with the *tone limit apparatus* for low tones, mentioned hereafter.

3. *A Tonometer,* consisting of 65 lingual tones; every subsequent tone by 4 vibrations (waves) higher than the previous one, from $\tilde{c} = 256$ to $\overline{\overline{c}} = 512$ vibrations in a second; with reed pipes.

4. *Tonometer,* consisting of 33 tones; each succeeding tone being 4 vibrations higher than the preceding one, from $c = 128$ to $\bar{c} = 256$ vibrations in the second.

(*Note.* By the number of vibrations given, double vibrations (waves) are always to be understood.)

5. *Tone-limit Apparatus,* for low (pitch) tones; consisting of 57 lingual tones, with reed pipes, from $c = 128$ vibrations downwards to 8 vibrations in a second, namely, from $c^{o} = 128$ to $C^{-1} = 64$, every subsequent tone in the descending scale by 4 vibrations lower than the next preceding tones from $C^{-1} = 64$ to $C^{-2} = 32$, each two vibrations lower, and, lastly, from $C^{-2} = 32$ vibrations downwards, each one vibration lower as far as 8 vibrations.

6. *Tone-limit Apparatus,* for high (pitch) tones; consisting of 31 small tuning-forks, the diatonic Durton scale c; d; e; f; g; a; h; c; 24 : 27 : 30 : 32 : 36 : 40 : 45 : 48. through 4½ octaves, namely, from $c^{iv} = 2048$ vibrations (double) to $c^{viii} = 40{,}960$ double vibrations, with two bows (fiddle-sticks).

In order to be able to observe, and to perceive better and more distinctly with the tone-limit apparatus for high tones (tuning-fork apparatus of 31 tuning forks), the ascending scale up to the highest pitch, it will be advisable to intonate with two bows (fiddle-sticks) the scales in octaves the one after the other, and thus to sound every tone with its octave simultaneously or one directly after the other.

7. *Two large Gedact Pipes* (stopped mouth pipes), whose pitch can be lowered an octave, with small wind chest and wind trunk, for illustrating the interference, waves, resultant tones, &c.

a. *Two smaller Gedact Pipes,* with small wind chest and wind trunk, for the same purpose.

b. Very powerful-sounding *Lingual (reed) Pipe,* accompanied by a large number of overtones, with bell-mouth: $C^{-2} = 32$ vibrations in a second.

c. *Twenty-nine Resonators* to the same, from the 4th to the 32nd overtone. (The resonators are conical, and made of zinc.)

d. *Reed pipe,* with bell-mouth, $C^{-1} = 64$ vibrations.

e. Four open and four stopped *Labral Pipes*, with small wind chest and valves, producing the C major accord : $\bar{c} : \bar{e} : \bar{g} : \bar{\bar{c}}$.
8:10:12:16

f. Accord Reed Pipe, producing the C major accord $c : e : g : \bar{c} : \bar{e} : \bar{g} : \bar{\bar{c}}$.
(The two apparatus *e* and *f* are for demonstrating the quality of sound.)

786. A Stand of Apparatus illustrating the progress of Æolian Principles.

J. Baillie Hamilton.

1. Primitive Æolian types.
   The rod.
   The bow.
   The harp.
2. Modern Æolian harp.
3. Wind concentrated upon a string, and applied to its entire length. By Professor Robinson.
4. Wind applied to a portion of the string, as by Wheatstone, Green, Isoard, &c.
5. Further modifications of the same.
6. Use of a free-reed. By Pape. The connexion with the string being effected by a silk thread.
7. Julian's mode. A metal string flattened into a tongue at the part where the wind impinges.
8. Farmer's mode. A reed-tongue substituted for the flattened portion.
9. Farmer and Hamilton's mode. A rigid connexion between reed-tongue and string allows the reed to be used as in reed-organs.

Subsequent Investigations by Hamilton in conjunction with Hermann Smith.

10. Improved string-organ note, in which a sympathetic resistance is offered to the string, the vibration transmitted to the soundboard, and constancy of pitch preserved by a spring-bow. The reed tone is modified by a tube, and the connexion effected through the tube by a "purse," the latter suggested by Hermann Smith.
11. Further modification by Hamilton. The necessity for the "purse" abolished by setting both reed and string inside the register. The economy of space effected by Hamilton's spiral spring, and the use of a short metal spring-bow.
12. Application of these improvements for use in a wind-viol. Also a conical string, invented by Hamilton, for obviating the following difficulties peculiar to reeds and strings in combination.
    a. The difficulty caused by the string breaking into segments, owing to the constraint on the reed, and the scarcity of notes obtainable.

b. By the irregularity of intervals which, in a cylindrical string, are crowded together near the reed, and are far apart when remote from it.

c. By the irregularity of tone in different portions of the string's length. When an ordinary string is used in short lengths the reed's motion is confined, and the tone is consequently pure; as the string lengthens, the tone becomes loose and coarse.

d. By the reducing of the string's bulk by stretching when tuned, as the reed remains constant the intervals would be changed when the string is thus attenuated.

The conical string meets these difficulties thus,—

a. The bulk of the string lies in the part used for playing upon, and thus no intervals are wasted.

b. The bulk is increased where the intervals would otherwise be wider.

c. The increasing bulk controls the reed equally at all points.

d. If tuned from the smaller end the string does not become attenuated, as more bulk is brought over the other bridge.

13. Apparatus for studying the relative amount of tone contributed through the string.

a. By the action of a soundboard and bridge.

b. By the reciprocal action of a spring-bow.

The spring-bow can also be rendered rigid, and the tone is then due merely to the constraining effect of the string on the reed's motion.

14. Æolian effects produced by percussion. For investigating the causes of the Æolian tone.

15. Apparatus investigating the most effective modes of—

a. Constraint upon a reed.

b. Transmission to a soundboard.

An intermediate mass is here used for transmission.

16. Apparatus showing how far quality of tone can be now affected by reaction from the soundboard. By placing a weight on different parts of the soundboard any quality of tone can be produced.

17. Further modifications for reducing these principles to practical use by altering the relation of levers and spring resistance, and substituting for the intermediate mass the structure of the register, which, as in No. 18, is itself the conductor to the soundboard.

18. Register embodying the foregoing improvements into a form for practical use, and illustrating the different forms of constraint applicable to reeds.

19. A new form of vibrator applicable to all solid bodies as

well as to columns of air. Invented by James Baillie Hamilton, April 1876.

20, 21, 22. Apparatus for studying the laws of strings combined with reeds.

IX.—EDUCATIONAL.

787. Apparatus for illustrating lectures. *Auguste Bel & Co.*

788. Graphical Representations of Musical Scales, on paste-board. *Gustav Schubring, Erfurt.*

The logarithms of the numbers of vibrations and their differences were first recognised by *Euler* (Leonhard Euler, tentamen morae theoriae musicae, 1739). These logarithms were at a later period used by *Opelt* ("Natur der "Musik," 1834, "Theorie der Musik") for the graphical representation of musical scales. *Herbart,* likewise, has employed them in his psychological speculations, and, lastly, *Prof. Drobisch* (Leipsic) has extensively applied them in his calculations of the musical intervals (Abhandlungen der fürstlich Jablonowskischen Gesellschaft, 1846).

The exhibited plates are especially intended to illustrate the musical scale calculations of Prof. Helmholtz; they agree in their annotations with those employed in the older edition of the "Lehre von der Tonempfindungen" (Part III., sections 15 and 16). A reconstruction of these plates, according to the annotations used in the new edition, is in course of execution.

789. Model for the Higher Tones.
Gustav Schubring, Erfurt.

Prof. Mach (Prague) has made use of the high-tone scales, drawn according to logarithmical scales, in order to produce a model for the high-scale tones. By means of the same not only can the higher tones of any sound be ascertained directly, but the higher tones of several sounds can also be compared the one with the other. Altogether the theory of the musical consonance and dissonance advanced by Prof. Helmholtz can be demonstrated thereby in the most excellent manner.

Prof. Mach's model had a length of three octaves, and contained the high tones according to the tempered free-balancing scale.

The model exhibited is more than four octaves long, and contains the high tones in the pure (natural) key.

789a. Model, similar to the two preceding, but not on paste-board. *Gustav Schubring, Erfurt.*

790. Sir Charles Wheatstone's Mechanical Illustration of the Vibration of Strings or Rods. *W. Groves.*

SECTION 7.—LIGHT.

WEST GALLERY, UPPER FLOOR, ROOM Q.

DETERMINATION—VELOCITY.

791. Original Apparatus, by M. Fizeau, for measuring the velocity of light. *Polytechnic School, Paris.*

792. Apparatus, by M. Foucault, for measuring the velocity of light. *Polytechnic School, Paris.*

I.—DISTRIBUTORS.

a. LENSES.

795. The Phakometer (Snellen), for the determination of the power of lenses (by the method of placing object and image at equal distances from the lens). *Dr. Snellen, Utrecht.*

The object (points of light on ground glass) and the screen upon which the image is received are moved in a perfectly similar manner, but in opposite directions, each by an enclosed steel spring.

For the determination of weak lenses, an auxiliary lens, No. 2·75, is placed on each side of the lens examined (at a distance of 0·025 from the centre).

The screen which receives the image moves alongside a scale, upon which at each double focal distance of the system of the three lenses (obtained by calculation) is marked the power of the lenses used in ophthalmological practice. Within $\frac{1}{20}$ "dioptric" one can with sufficient accuracy estimate how much the lens examined differs from the powers marked on the scale.

The image having constantly the same magnitude, precise adjustment is easy. The screen possesses a diagram of the image. The image of the points of light covering this diagram, the centre of the glass coincides with the diameter of the instrument. Not only the focus, but also the centre can be determined directly.

The scale may be controlled at any time by determining the strong glasses directly, the auxiliary lenses being removed. Then the double-focal distance is to be taken from the corresponding principal plane to the point where the image is formed.

The instrument as yet is only adapted for symmetrical (biconvex) lenses. In order to determine plano-convex or periscopic glasses, it will be best to place two glasses of equal power one against the other, so as to obtain a symmetrical form. According to the calculated principal planes of this system, a scale may be computed.

796. Lens of Stokes, with constant axis (Snellen); consisting of a negative and a positive cylindrical lens rotating equally, but in opposite directions. (Graefe's Archiv für Ophthalmologie, 1873, XIX. 1, p. 70.) *Dr. Snellen, Utrecht.*

Two cylindrical lenses ($C-\frac{1}{10}$ and $C+\frac{1}{10}$) placed centred one before the other can rotate about an axis perpendicular to the plane of the glasses, equally, but in opposite directions, and by means of inclosed steel springs. The principal meridians of the system remain here with the same direction. The refraction in the principal meridians changes with the rotation proportionately to the sines of the angle between the axes of the cylinders. Hereupon has been constructed the scale which is to be read on the rim of one of the glasses. For the determination of the refraction, parallel lines are viewed through this lens of changeable power, the lines are perpendicular on one of the principal meridians, and placed either at a distance or united with the lens in a tube. Manufactured by A. Crétès, optician, Paris.

797. Set of Spherical Lenses, metrical system (by Roulot). *Prof. Donders, Utrecht.*

798. Early Stereoscope, made by the late Sir David Brewster, the inventor of that instrument. *John Maclauchlan.*

798a. Early Stereoscopic Pictures, prior to the application of photography. From the collection of the late Sir C. Wheatstone. *Robert Sabine.*

798b. Early Stereoscopic Pictures. Daguerreotypes of 1, Biot; 2, Bequerel; 3, Foucault, from the collection of the late Sir C. Wheatstone. *Robert Sabine.*

798c. Seven Earliest designs for the Stereoscope printed in black and white. From the collection of the late Sir C. Wheatstone. *Robert Sabine.*

798d. Early Stereoscopic Pictures. Two Daguerreotypes of Faraday, from the collection of the late Sir C. Wheatstone. *Robert Sabine.*

799. Double Opera Glass. An early example, probably made in Holland about 1700. *South Kensington Museum.*

801. Galilei's double perspective, No. 17.

802. The same, No. 29.

803. The same, No. 37.
Voigtländer and Son (Chevalier von Voigtländer), Brunswick.

804. Telescope.
Voigtländer and Son (Chevalier von Voigtländer), Brunswick.

806. A Quartz Ball. *A. Hilger.*

807. An Iceland Spar Ball. *A. Hilger.*

808. Lens, by Stocker, modified by Dr. Snellen. The system indicated above has been utilized with two cylindrical glasses ($\times 12° = 12°$). When the cylindrical surfaces are parallel, their refraction becomes annulled ; when they are crossed, they become added. The axis is fixed for the same reasons as above.
M. Crétès, Paris.

810. Series of Metrical Glasses. The dioptric unit is a lens of one metre focus ; the lens 0·50 to two metres focus is a semi-dioptric value of the unit ; the lens 2 to 0·50 focus is a dioptric value of double the unit. The same rule applies to all the other lenses in the collection. *M. Crétès, Paris.*

810a. Globe made of Spar. *M. Lutz, Paris.*

811. Early form of Stereoscope.
Wheatstone Collection of Physical Apparatus, King's College, London.

812. Early form of Stereoscope.
Wheatstone Collection of Physical Apparatus, King's College, London.

812a. The Polistereoscope.—Apparatus which serves as telestereoscope, pseudoscope, iconoscope, &c., &c.
Augustus Righi, Professor of Natural Philosophy, Royal Technical Institute, Bologna (Italy).

This apparatus consists of two plane mirrors, one of which (on the left in the figures) can turn about an horizontal and a vertical axis; the other mirror, besides these movements, can be fixed at different distances from the former. The eyes must be applied at two cylindrical tubes fixed to a diaphragm, which can take different positions. One of the eyes sees directly the objects, while the other sees the same object but apparently in a different position. This virtual position can be determined by forming the image of the eye, given by the left mirror, and after the image of the point so determined in relation to the other mirror. If objects not too near are observed the illusion succeeds equally, though the image in the eye which sees by reflection is smaller than the other. According to the inclination which is given to the mirrors, it is possible to make any determinate point of the observed objects appear in the true position.

Fig. 1.—If the apparatus be placed as in Figure 1, it produces the effect of the telestereoscope.

Fig. 2.—Placed as in Figure 2, it acts as a pseudoscope. According to the distance between the mirror, diminution or augmentation of relief can be obtained, or an inversion of relief. Some curious effects (which cannot be obtained with a Wheatstone's pseudoscope) are observed by looking at rotating geometrical solids, constructed with metallic wire, or by looking at these solids while the observer moves round them.

Fig. 3.—With the apparatus placed as in Figure 3, the effects of an iconoscope are obtained. A very narrow mirror is substituted.

Fig. 4.—In Fig. 4 the apparatus is placed so that the eyes see the objects as if they were in a same plane perpendicular to the right line which joins the

eyes; the relief in objects made with vertical wires then disappears. If the diaphragm which bears the two tubes is kept fixed, and the instrument turned slowly round the left tube, very curious apparent motions occur in the objects under observation.

For the mathematical theory of this apparatus, *see* the "Nuovo Cimento," 2d ser. t. xiv.

813. Jewel Lens (Ruby) of $\frac{1}{60}$ inch focus. Made by Mr. Andrew Pritchard, at the suggestion of Sir David Brewster.

(*See* Brewster's "Optics," 1831, p. 337.) *John Spiller, F.C.S.*

813a. Vertical Apparatus for Projections.
M. J. Duboscq, Paris.

813b. Projecting Apparatus, for all phenomena of double refraction and polarization. *M. J. Duboscq, Paris.*

813c. Support, with Reflector, by Fresnel.
M. J. Duboscq, Paris.

b. Lanterns, Cameras, &c.

814. Oxy-hydrogen Lantern, of new form, suitable for lecturers. *C. J. Woodward.*

The lantern is mounted on a "Willis's stool," so that supports of various kinds may readily be attached. The body of the lantern is swung between two uprights, and can be clamped so as to send a beam of light at any angle; this, combined with a rotatory motion in a horizontal plane, enables the lecturer to direct a beam in any required direction. A rod carries lenses and a mirror when it is required to throw the light vertically upwards on an object, as, *e.g.*, for cohesion figures.

816. Camera Obscura. An early example, said to have belonged to Sir Joshua Reynolds. *South Kensington Museum.*

This camera when closed has the form of a large folio leather-bound book. It is recorded to have been given by Sir Joshua Reynolds to Lady Yates, by whose great grand-daughter, Mrs. J. R. Harrison, it was, in May 1875, presented to the Museum.

816a. Camera, by Colonel Laussedat. *M. Lutz, Paris.*

816d. Camera Lucida, invented and used by Dr. Wollaston.
G. H. Wollaston, Clifton.

816g. Camera Lucida, with slight magnifying power.
A. Nachet, Paris.

816h. Camera for Landscapes, by M. Gori.
A. Nachet, Paris.

816i. Camera Lucida, invented and used by Dr. W. H. Wollaston. *G. H. Wollaston.*

817. Improved Electric Lamp and Lantern for Lecturer's use. *John Browning.*

The lamp is automatic, the carbon poles being drawn asunder in proportion to the strength of the battery power used; this is effected by drawing iron rods into a hollow coil of insulated copper wire. The lantern has two nozzles, one intended for exhibiting screen experiments in spectrum analysis, polarisation, refraction, reflection, diffraction, &c. The second nozzle is for exhibiting diagrams on the same screen, without altering the arrangement of the apparatus for physical experiments.

818. Lithographs for the Stereoscope, from drawings by J. Müller, Hessemer, Oppel, Nell.

J. Wilhelm Albert, Frankfort-on-Maine.

The coloured drawing marked with A (upon grey cardboard) is the original made by the late Prof. *Müller*. Images 2, 3, and 4 serve for a stereoscope without glass. The other images refer to stereometrical, astronomical, and optical (colour combinations) subjects. Some images appear, by a slight change of position, in low or high relief.

819. Edelmann's Spectral Lamp, for the projection of the spectra. *M. Ph. Edelmann, Munich.*

820. Printed Treatise to the same.

M. Ph. Edelmann, Munich.

821. Duboscq's Lantern. To be used in connexion with the following apparatus:—

1. Top with illuminating lens; is to be employed with spectral slit and polariscope.

2. Spectral slit; can be regulated by means of a fine screw.

3. Stand with convex lens; serves for the projection of the rays in spectrum experiments.

4. Two hollow prisms.

5. A prism plate for two prisms, arranged for being turned and put higher or lower.

6. Stand with holder for a prism; can be regulated.

7. Polariscope.

8. Lens system, with four-inch illuminating lenses and achromatic objective; serves for the projection of photographic and other glass images of about 3 inches in diameter.

9. Microscope. This can be screwed to the end of the preceding system of lenses, after the objective has been removed.

10. Regulator for producing electric light; can be regulated.

11. Hydro-oxygen gas lamp.

12. Apparatus for hydro-oxygen illumination, arranged for the projection of opaque objects.

A. Krüss, Hamburg.

821a. Photogenic Lantern. *M. J. Duboscq, Paris.*

822. Double demonstrating Oxy-hydrogen Lantern, with triple condensers, consisting of two 10-inch plano-convex

lenses, and a 7-inch meniscus, next to the source of light. The last lens is made to slide backward and forward between guides, so as to increase or diminish the cone of rays, and enable large or small diagrams or pictures to be exhibited without material distortion. *Made and exhibited by Dr. Stone.*

823. Magnesium Lamp, provided with brass cylinders and reflector. *A. Herbst, Berlin.*

824. Brewster's Patent Kaleidoscope (with case). The original form of the instrument made by Bate, of London, in the year 1815. (Position of the reflectors capable of adjustment, non-central eye piece, and rotating terminal disc, or box containing the coloured glass.) *John Spiller, F.C.S.*

II.—SELECTORS.

a. Spectroscopes, Prisms, &c.

825. Photographic and **Spectrophotographic Specimens** and **Apparatus** of Sir John Herschel and Sir William Herschel. *Prof. A. S. Herschel.*

1. Original fragments and complete photographs on glass with chloride of silver of the forty foot telescope at Slough. Produced in 1839 by Sir John Herschel, as a new modification of the process of Daguerre. Paper wrapper of the specimens inscribed in autograph by Sir John Herschel with the above description of the plates.

2. Prismatic apparatus designed and used in researches on the photographic action of the different rays of the spectrum, by Sir John Herschel, Slough, 1839. Original description, and notes of experiments with the instrument extracted from MS. journal. Specimens of photographed spectra obtained with the instrument by Sir John Herschel, at Collingwood, in 1859.

3. Heliostatic mirror (used by fixing outside to aperture in a window shutter, and turning screws by hand inside to direct the sun's rays horizontally or in a required direction). Glass prism to receive and bend downwards the reflected ray to a table on which thermometers were exposed to action of the different rays of its spectrum. Constructed and used (with other apparatus not preserved) by Sir William Herschel, in experiments on thermal radiation in the solar spectrum, described in the Philosophical Transactions, 1800–1801.

A plate of light blue cobalt glass, mounted on cardboard diaphragm, pierced with an eye-hole; used with the prismatic photographing apparatus to examine test papers submitted to the solar spectrum (before sensitizing), and to place a pencil mark or other datum line on the test paper in the exact position of the yellow ray. When thus adjusted and fastened to the support, the sensitive solution to be tested, if not already present in the paper, was applied to its exposed surface with a brush, and the time of exposure and intensity of the direct sunlight was at the same time recorded. Two small card-leaves have, for the purpose of examination, been attached to the cardboard diaphragm, by closing which upon the glass, the "fiducial" yellow ray transmitted by blue cobalt glass will be observed with the accompanying eye-piece of a small pocket spectroscope placed with the plate, showing through the

narrow slit left between them the selective absorption of the glass, when ordinary white light is examined and spectroscopically analysed by means of the dispersion of the prisms.

825a. Fluorescent Eye-piece, by M. Soret, for adaptation to the **Spectroscope.**

Geneva Association for Constructing Scientific Instruments.

It consists of a plate made of a fluorescent and transparent substance (uranium glass or different liquids contained between two glass plates), which is placed in the glass of the spectroscope at the focus of the objective. The ultra-purple spectrum projected upon this plate becomes visible, and it is observed through an eye-piece which is inclinable upon the axis of the glass. A very intense light is necessary. (For description of this apparatus, *see* Poggendorff's Annalen, 1274. Jubelband, p. 407; Archives des Sciences physiques et naturelles, 1874, vol. 41, p. 338; and 1875, vol. 54, p. 255.)

825b. Apparatus used by **Sir C. Wheatstone** in his early researches in **Spectrum Analysis.** *R. Sabine.*

825c. Arrangement of Apparatus for Experiments on the Assay of Gold Alloys, by means of the Spectroscope, in the manner suggested by Mr. Lockyer.

W. Chandler Roberts, F.R.S., Chemist of the Mint.

The apparatus consists of:—

(1.) An induction coil, capable of giving a 10-inch spark in air, which is provided with a Foucault contact breaker in order that the spark may be perfectly continuous.

(2.) A frame on which the portions of metal under examination can be so arranged as to be easily brought in succession under a fixed pole of aluminium. Accompanying this frame is a fixed microscope provided with cross wires in the eye-piece, and the table bearing the assay pieces can be adjusted by a micrometer screw, so that the image of the apex of each assay piece can be brought to coincide with the cross wires, thus ensuring that the striking distance remains constant.

(3.) A lens to throw an image of the spark on the slit of—

(4.) A large spectroscope in which the spectra of the alloys are examined. It is provided with a micrometer, the wires of which are horizontal and move in a vertical plane.

When a spark from the induction coil (the two terminals of which are also connected with the coatings of a Leyden jar) passes between the aluminium pole and one of the alloys, an atmosphere of the vapours of gold and copper is formed round the lower pole which does not extend to the upper pole, and therefore in the spectrum observed the lines due to these metals will not cross the field of view. Mr. Lockyer observed, that, when all other conditions remain the same, if the composition of the alloy be slightly altered, the relative heights and intensities of the lines of the two metals vary. For these comparisons the gold line having a wave length of 5,230 tenth-metres, and the copper line 5,217, are the most convenient. If a series of known alloys varying slightly in composition is examined, a curve may be constructed, the ordinates of which represent the ordinary assays, and the abscissæ the micrometer readings for the points at which the above two lines are equally bright, and then, theoretically, if an unknown alloy of about the same composition be examined, this curve enables us to determine its exact composition when the micrometer reading is known.

In practice, however, it is found necessary to vary the striking distance with the composition, and the amount of this variation is still under investigation.

826. Spectroscope for determining the smallest displacement of spectral lines, and for measuring velocity of motion.
Professor Carl Wenzel Zenger, Prague.

This new instrument gives double images, two spectra produced by an additional prism of quartz or calcspar, giving two dark lines in parallel directions, *e.g.*, the D. line, and of constant distance, if there be no motion towards or from the luminous body. The motion of heavenly bodies producing, therefore, the displacement of both D lines, and an accurate micrometer measuring it, gives the amount of velocity.

827. Hermann's Taomatoscope, for examination and demonstration of absorption bands in fluids by the spectroscope.
Professor Dr. L. Hermann, Zürich.

The fluid is poured into the little chamber, and the thickness of the layer is regulated by sliding the inner tube until the bands appear.

828. The Collection of Prisms of crown and flint glass used in the construction of refractors and spectroscopes by Steinheil and Merr at Munich, and by Hofmann at Paris, whose refractive indices for 50 lines in the solar spectrum were determined by Prof. Van de Willigen. *Foundation Teyler at Haarlem.*

Steinheil No. I. flint, No. II. flint, No. III. crown glass.

Merr No. I. and No. II. both of the same heaviest flint, No. III. crown, No. IV. crown, No. V. and No. V*a*. both of the same ordinary flint glass.

Hofmann No. I. heavy flint glass.

See "Archives du Musée Teyler," Vol. I. p. 31, 64 and 205, and Vol. II. p. 183.

See the chemical composition of crown Steinheil No. III., and Merr No. IV., and of flint: Steinheil No. II., Merr No. I. and No. II., and No. V. and No. V*a*., and Hofmann No. I., given by Prof. P. J. van Kerckhoff, "Archives du Musée Teyler," Vol. III. p. 117.

Steinheil No. II. and No. III., Merr No. I. and No. II., No. IV. and No. V. and No. V*a*., and Hofmann No. I. are accompanied by parallelopipeds and plates of the same glass and by pieces or powder for chemical analysis.

829. Powerful Spectroscope, with Browning's automatic action, for adjusting the prisms to the minimum angle of deviation of the ray under examination. *John Browning.*

In this instrument the ray can be made to pass four times through the six prisms, and a dispersive power of 24 prisms thus obtained can be used, or that of any lesser number of prisms at pleasure. The instrument is fitted with a new reflecting bright line micrometer; when measuring with this contrivance no light is visible in the field of view, but the wires of the micrometer are seen faintly illuminated.

830. Universal Spectroscope, with Browning's automatic action, giving a dispersive power of from 2 to 12 prisms.
John Browning.

831. Spectrometer, straight sighted, with apparatus for registering observations.

Geneva Association for Constructing Scientific Instruments.

This straight-sighted spectrometer is distinguished from others of the same description, in that the distance of the rays of the spectrum is measured, not by the superposition of the spectrum sighted upon a lighted micrometric scale, but by measuring the angle formed by the eye-piece for marking the reticle of the telescope from one line upon the other, and then comparing with the angle formed by the telescope pointed on two lines of known distance. A tangent screw effects the angular displacement of the telescope; this screw bears a calculator which serves to read angular displacements of less than 20 seconds. A recorder, formed of a movable pencil which acts upon a counter, serves to make series of observations in the dark. The telescope of the line of collimation which bears the slit, possesses also an angular motion which serves to bring any portion whatever of the spectrum in the centre of the compass of the eye-piece.

832. General Apparatus for Spectroscopy, Polarisation, Reflexion, Refraction, and for various experiments in **Fluorescence.**

Geneva Association for Constructing Scientific Instruments.

This apparatus has been constructed with the object of carrying out, with one and the same instrument, all, or nearly all, experiments in spectroscopy, rotatory polarisation, reflection, and refraction. The divided circle is movable around an axis, and serves to bring the rays of light at any angle upon the eye-piece of the line of collimation. For experiments in spectroscopy, a table of one, three, or six prisms may be set up. The prisms are raised above the divided circle sufficiently to allow of their being heated from below if required. For determination of the line of collimation suitable arrangements have been provided, and for experiments in polarisation, eye-pieces fitted with divided circles and nicols; a Babinet compensator may also be adapted to them.

The first apparatus of this kind was constructed for the use of Professor Wiedemann, of the University of Leipzig.

833. Large Spectrometer, according to Meyerstein's system, for determining the relations of refraction and dispersion of different media, with contrivance for polarisation.

Schmidt and Haensch, Berlin.

834. Smaller Spectrometer, of the exhibitors' own construction. *Schmidt and Haensch, Berlin.*

835. Spectrometer, according to Abbé's system, with divided circle of 20 cm. diameter, repetition circle, and micrometer apparatus for determining the dispersion. Additional to the same, a hollow prism with metal body. *Carl Zeiss, Jena.*

The spectrometer has only *one* telescope, which serves at the same time as collimator and as instrument of observation. The adjustment brings about automatically the minimum of deviation for every ray. The measurement of the refracting angle and that of the deviation takes place without

change in the instrument. The determination of the dispersion is effected, independently of ascertaining the absolute refraction index of *one* colour, by micrometric measurement of the angle.

836. Two Prisms of Glass, for observing the **dispersion** of coloured liquids; constructed by Steinheil, of Munich.

Professor Kundt, Strassburg.

The refracting edge of the hollow prisms is so sharp that they show the dispersion of even highly coloured liquids.

837. Spectrometer, with five-inch circle, according to Dr. Meyerstein's system, for measuring the refraction and dispersion of different media, for chemical and optical analysis, as well as for all kinds of goniometrical measurements.

There are belonging to this :—

a. A small circle with pivot and plate.
b. A telescope with stand.
c. A slit tube (Spaltrohr).
d. A scale tube.
e. A crystal stand.
f. A prism.

Aug. Becker (*Dr. Meyerstein's Astronomical and Physical Workshops*), *Göttingen.*

The telescopes, when required, are screwed on to the places marked "Fernrohr," "Spaltrohr," &c. The small circle is put into the middle of the larger one. To determine the refracting angle of a prism, the telescope is attached to that part of the instrument which is marked "Zur Bestinmung, &c.," it is left here for all goniometric measurements, but the smaller circle is removed and the crystal-holder put into its place.

838. Spectrometer, of the latest construction, according to Dr. Meyerstein's system, arranged for the relations of refraction and dispersion of different media, for the reflection of polarised light at the free surface of liquids, as well as for the reflection of solid bodies, for all kinds of goniometrical measurements, and for chemical and optical analysis.

There are belonging to this :—

a. A small circle with plate.
b. Two telescopes.
c. Two slit-tubes (Spaltrohre).
d. One scale-tube.
e. A Babinet's compensator.
f. Two weights for balancing telescope and split in a vertical position.
g. A crystal stand.
h. A flint-glass prism.

Aug. Becker (*Dr. Meyerstein's Astronomical and Physical Workshops*), *Göttingen.*

For attaching the telescopes, collimators, &c., the same rules apply as in the previous case. The larger telescope and collimator serve for deter-

mining the refraction and the refracting angle; the small tubes are for the polarisation. Determination of refraction and of refracting angles are effected as with the larger instrument, except that the telescope is put into the place of the micrometric tube. Solid bodies, when submitted to polarisation, are fixed with some wax against the plate which is put up in the black dish. When liquids are to be investigated, the small circle with its clamps is entirely removed, the screw, which maintains the principal circle in horizontal position, taken out, and the instrument turned down until the main circle stands quite vertically, when it is fixed again by the screw. For all polarisation experiments *Babinet* compensator is fixed by means of the two screws upon the bearer of the telescope.

839. A hollow Prism, according to Dr. Meyerstein, which is used for optical analysis with the spectrometer.

Aug. Becker (Dr. Meyerstein's Astronomical and Physical Workshops), Göttingen.

840. Rigid Spectroscope by Browning, constructed for Mr. Gassiot on the design of Dr. Balfour Stewart, with the view of determining whether the position of the D lines of the spectrum is constant, whilst the co-efficient of terrestrial gravity is made to vary. *Kew Committee of the Royal Society, Kew Observatory.*

It is described in the Proceedings of the Royal Society, Vol. XIV., p. 320.

Observations were made by it from 1866–1869, on board H.M.S. "Nassau," during a voyage to and from the South Pacific, and subsequently at the Kew Observatory until 1872, the results of which are not yet published.

It consists of a train of three prisms, the last of which is silvered on one side, so as to return the light which falls upon it. Close to the slit another prism is placed, which reflects the rays on their way back into a micrometer, by which the position of the D lines is measured."

841. Vierordt Spectroscope, adapted for the measurement of absorption spectra and for quantitative chemical analysis.

Franz Schmidt and Haensch, Berlin.

This apparatus is described in Vierordt's work on the "Application of the Spectroscope to the Photometry of Absorption Spectra, and in Quantitative " Chemical Analysis." Tübingen, 1873.

842. Browning Spectroscope, applicable to the examination of absorption spectra, according to Vogel's method.

Franz Schmidt and Haensch, Berlin.

843. Mitscherlich's Stand for use in the spectroscopic examination of coloured flames.

Professor A. Mitscherlich, Münden.

844. Pocket Spectroscope, showing sodium line in a simple burning candle, of great use in chemical and meteorological observations. *A. Hilger, London.*

845. Hilger's Pocket Spectroscope, showing all the principal Fraunhofer lines, dividing D easily with nickel line between; when on sun, a sliding slit with division adjustable to position, besides a limb in front of eye-piece. *A. Hilger, London.*

846. Pocket Spectroscope of the simplest and cheapest kind. *A. Hilger, London.*

847. Two perfect Right-angle Prisms. *A. Hilger.*

848. Nicol and a Double Image Prism. *A. Hilger.*

849. Spectroscope made by Yeates, of Dublin, fitted with a diaphragm instead of cross threads for measurement of position of lines. *Professor Jos. P. O'Reilly.*

The diaphragm, above, being perfectly opaque, is always visible against even the faintest lines; moreover, it dispenses with the introduction of an extraneous light which may by its brilliancy interfere with that of faint lines. This spectroscope is specially adapted for the examination of fluorescent minerals, the prisms and lenses being of quartz.

850. Spectroscope, with bi-sulphide of carbon prisms and lens, arranged for projection. *Yeates & Sons.*

The prisms and collimating lens are so proportioned that no light is lost by passing outside the prisms or otherwise.

851. Spectroscope, with compound prism and angular scale. *Yeates & Sons.*

852. Spectroscope, with two prisms. *James How & Co.*

853. Three Foucault's Prisms.

Fluor-spar, cut in three directions.
Small rhombohedron of fluor-spar.
Cone and pyramid (black) for Guérard's apparatus.
Cone for the projection of annular spectrum.
Pyramid for the projection of four spectra.
M. Mascart's prism.
Small prism of crown glass.
Two polyprisms (glass).
One polyprism (quartz).
Collection of nine prisms.
Boscowich prisms.
Fresnel's tri-prism.

Laurent (Paris).

854. Prisms for direct Vision in 3 pieces.

„ „ „ **5** „
„ „ „ **7** „
Rochon prism.
Wollaston prism.
„ „ (small).
Fluor-spar prism.
Cube of fluor-spar.
Fluor-spar lens.
Three cells for spectroscopic work.
A collection of quartz and fluor-spar prisms.
Spectroscope with one prism.
Object-glass for projecting ray spectra.

Laurent.

854a. Collection of Prisms, for optical purposes. *Laurent, Paris.*

854b. Spectroscope. *M. J. Duboscq, Paris.*

854c. Prisms, by Arago. *Paris Observatory.*

854d. Prisms, by Borda. *Paris Observatory.*

854e. Collection of Compounds of Silicon with various **Metals** for optical purposes. *Feil, Paris.*

1. Disc of Crown Glass, 4 inches.
2. Disc of Flint Glass, 4 inches.
3. Plate of Crown Glass (heavy English).
4. Parallelopiped, of ordinary flint glass.
5. Crown Glass Prism.
6. Flint Glass Prism.
7. Flint Glass Prism, (sp. gravity 4·4.)

7a. Prism manufactured by Fraunhaufer Guinand.

8. Flint Glass Prism (very heavy), sp. gr. 4·4.
9. Flint Glass Prism, sp. gravity 4.
10. Flint Glass Prism, sp. gravity 5·2.
11. Flint Glass Prism, sp. gravity 5·5; samples by the dry method.

11a. Silicate of Potassium and Calcium with Titanium.

12. Aluminate of Silicium and Magnetism.
13. Crystallisation of Alumina and Magnesia.
14. Crystallisation of Fluosilicate of Magnesium and Calcium.
15. Alumina and Magnesia Crystallised by Fluosilicate of Potassium.
16. Crystallisation of Fluosilicate of Aluminium.
17. Crystallisation of Barosilicate of Aluminium.
18. Crystallised Aluminate of Magnesium and Silicium.
19. Manufacture of Adamantine Boron.
20. Plate of Crystals of Aluminium.
21. Blue Obsidian.
22. Obsidian coloured by Cobalt.
23. Samples of Crown Glass, extra white.

854f. Objective of Rock Crystal, 10 centimetres in diameter. *M. Lutz, Paris.*

854g. Astronomical Glasses, for cabinets of physics. *M. Lutz, Paris.*

855. Micro-spectroscope. Spectral ocular with prism for comparing two spectra, and with Abbé's measuring apparatus for the direct estimation of the wave lengths of dark or bright lines in a spectrum. In case. *C. Zeiss, of Jena.*

This spectroscope gives the position of the bright or dark lines by means of a scale on which the spectrum is thrown, and which, by means of its peculiar

graduation and numbering, allows the wave lengths at any place to be read off in micro-millimetres.

856. Apps' Improved Gas and Electrode Holder for Spectrum Analysis. *Alfred Apps.*

857. Improved Automatic Chemical Spectroscope, invented and made by the contributor. The object glasses and prisms by Chas. Owen, Optician, Strand.

Rev. Nicholas Brady, M.A.

Prisms with a circular face are cemented to the object glasses of the collimator and telescope, the circular face of the prisms being of the same size as the object glass. The base is rectangular to the surface of the object glass, and the refracting angle about 30°. The beam of light rendered parallel by the collimating lens passes through the first half prism perpendicularly and suffers no refraction, but is refracted on emergence from its exterior face; the refracted and dispersed beam is received on the external face of a second object glass prism, suffers more refraction and dispersion, and, emerging at a perpendicular incidence, is taken up and brought to a focus by the object glass. In all positions the ray under examination passes parallel to the base of the prisms, and therefore at the angle of minimum deviation. The variation of the angle between the two prisms by the motion of the tangent screw of the telescope merely brings one ray after another into the field of view. This automatic arrangement gives a dispersion equal to one dense glass prism of 50°. Should greater dispersion be required I have arranged a prism of 60° in the centre of the instrument, which by a very simple automatic contrivance of one lever and a slot is moved by the arm carrying the telescope, so that any ray is still preserved at the angle of minimum deviation. A further advantage of this new principle is, that with these object glass prisms the field is completely filled with light, which has never usually been the case, unless the prisms are extra large, and therefore expensive; and if a train of prisms be inserted their faces only require to be equal for them still to entirely illumine the field: thus much light is gained, and comparatively little is lost by absorption and reflection, as the surfaces are fewer, so that the violet end of the spectrum is very extensive, and the lines beautifully defined.

858. Gas Lamp Apparatus for placing before the slit of the spectroscope with Bunsen burners, &c., insuring the proper adjustment of the platinum wires carrying the substance under examination in the flame without displacing the eye from the ocular of the telescope; and also an arrangement for quickly and efficiently exchanging one or both burners for either one or two vacuum tubes. *Rev. Nicholas Brady, M.A.*

Two photographs accompany the instrument, showing its use in two different positions.

859. Ordinary Spectroscope, arranged for the exhibition of diffraction phenomena, with aperture and gratings, &c. of various kinds under common and polarised light, and with the means of observing the spectra of the diffracted beam. Designed and made by contributor. *Rev. Nicholas Brady, M.A.*

b. POLARISCOPES, &c.

861. Jellett's Saccharometer, for the measurement of the rotation which certain fluids are capable of producing in the plane of polarisation of the transmitted ray. *Rev. John H. Jellett.*

This rotation is measured by the method of compensation, the original position of the plane being restored by transmission through a column of fluid possessing an opposite rotatory power. This fluid is contained in a vessel closed at the bottom with glass, and the length of the column is regulated by means of a tube, also closed with glass, which is capable of moving in the direction of its axis, the amount of this movement being read off on a scale.

A full description of the instrument and of the analysing prism used in its construction is given in the "Transactions of the Royal Irish Academy," Vol. XXV., pp. 373–82.

861a. Laurent Polarimeter and Saccharometer, with two divisions on the plate, with inversion tube and one thermometer. *Laurent, Paris.*

861b. Saccharometer, by Soleil, with penumbra (large model). *M. J. Duboscq, Paris.*

861c. Large Circle, by Messrs. Jamin and Sénarmont. *M. J. Duboscq, Paris.*

861d. Large Circle for measuring the elements of elliptic and rotatory polarization in solids and liquids, and reproducing all impressions of polarization and refraction. (This apparatus belongs to the School of Photography.) *M. Lutz, Paris.*

862. Polarising Apparatus, according to Dove's system, complete, with polyoscope and dichroscope. *Schmidt and Haensch, Berlin.*

863. Simple, handy Polarising Apparatus, according to Carl's system. *Schmidt and Haensch, Berlin.*

864. Melde's Models, for illustrating the **colours of thin leaves** in polarised light. *Ferdinand Süss, Marburg.*

865. Melde's Model, for illustrating **circular polarisation** by means of gypsum and scales of mica. *Ferdinand Süss, Marburg.*

866. Paste-board Models, according to J. Müller's system, for illustrating the **colour phenomena** in **polarised light,** and the **uni-axial** and **bi-axial crystals.** *J. Wilhelm Albert, Frankfort-on-Maine.*

Ten models of cardboard, together with a treatise on them. Described in *J. Müller's* "Lehrb. der Phys., 7 Aufl., I. Bd., 3tes. Buch, caps. 9 and 10."

867. Polarising Apparatus, for projection with rotatory analyser, according to E. Mack's system, with quartz plate and $\frac{1}{4}$ undulation plate. (Comp. Poggendorff's Ann., 1875, No. 12.) *J. Wilhelm Albert, Frankfort-on-Maine.*

The ray of sun or electric lamp falls through a Nicol, which is protected with a shade, upon a press, in which the object is fastened by means of spring clamps, and passes thence through a tube which can be rotated with great velocity. This tube is provided at one end with a shade capable of rotating with the tube, and the analysing Nicol over which there is a slit or a square aperture.

At the end of the tube is a deflection prism of crown glass, to which, for some investigations, a direct vision prism is added. The ray, as it issues from the tube, is received by a lens, which throws upon a screen a sharp image of the slit or square aperture. This image moves in a circle as the azimuth changes, and thus shows by quick rotation all the phenomena which, in ordinary polarising instruments, appear successively *side by side.*

868. Twelve Plates with Pictures, of gypsum and mica, for polarised light. *Professor Karsten, Rostock.*

The form of images has been chosen to represent the different colours of thin plates in polarised light. Any kind of polarising apparatus may be employed for these observations.

869. Nörremberg's Polarising Apparatus. *W. Apel, Göttingen.*

870. Nörremberg's Polarising Apparatus, large size; according to the design of Professor Listing. *W. Apel, Göttingen.*

(2.) The apparatus serves not only for purposes of lecture demonstration, but also for accurate measurements. The advantage of the instrument over the ordinary polarising microscopes lies in the circumstance that in the *Nörremberg* apparatus the polarised light passes to and fro through the same crystal plate. The movable glass plate of the middle table serves for measuring the angle of the optical axis by means of a graduated semi-circle.

870a. Large Apparatus by Norremberg, improved by Wheatstone. *M. Lutz, Paris.*

870b. Telescope used for observing the **Polarisation** of **Light** in **Water.** *J. Louis Soret, Geneva.*

The telescope is closed on the objective side by a glass pane. The eye-piece is formed of a " Nicol " prism.

The observer, placed in a boat, immerses the objective end of the telescope and looks through the " Nicol." He then finds the light of blue coloration reflected by the lower strata on the surface of the water, and by turning the Nicol ascertains if it is polarised.

See " Notes sur la Polarisation de la Lumière de l'Eau." Archives des Sciences physiques et naturelles, 1869, Vol. 35, p. 84, and 1870, Vol. 39, p. 352.

871. Apparatus for the Observation and Measurement of the cyclopolar double refraction of Quartz in the direction of the optical axis. Designed by Professor Listing, executed by R. Winkel in Göttingen.

Royal Mathematical and Physical Institute of the University of Göttingen, Prof. Listing.

The telescope can, before being put into the holder of the apparatus, be adjusted for far off objects, or for an object of but 2–3 meters distance from the object glass. The *Fresnel* triple quartz prism is fixed in upright position in the support below the telescope, and protected by a cardboard shade against side lights. By means of the achromatic lens, situated below the prism, a virtual image is produced of an appropriate object (line cut by a diamond upon glass, &c.), placed upon the black table, which image, when seen sharp and double in the telescope, will be just as distant from the object glass of the telescope as the latter has been adjusted for. The magnitude of the duplication is read off from the micrometer in the ocular tube, and from the number obtained the diversion of the two rays after their passage through the triple prism is calculated. The ocular can now be provided with tourmaline and $\frac{1}{4}$ mica plate, which may be used singly or combined. The tourmaline alone, shows, on turning, in all azimuths, the double image without alteration of intensity in the component parts; the two rays undergo, therefore, neither linear (plain) nor elliptical polarisation. The tourmaline, with mica plate below it, shows, as well known, that both rays are circularly polarised, the one right, the other left; the tourmaline must in this case be so adjusted that its line of principal action be azimuth 0° or 90°, and the main section of the interposed mica plate is turned to form with that line $\pm 45°$.

The aim of the measurements is to determine the refraction indices of the two rays of opposite circular polarisation, propagated with unequal velocity along the optical axis of the quartz.

872. Stauroscope, according to the design of F. von Kobell, executed by Bochur and Wiedemann.

Prof. Dr. Franz von Kobell, Munich.

873. Analysing Prism of **Iceland Spar,** made by the inventor, the late William Nicol, in his 80th year.

Edinburgh Museum of Science and Art.

The Nicol prism is so constructed that only one polarised ray can pass through it.

873a. A Nicol's Prism for Polarising Light, by C. D. Ahrens. *W. Spottiswoode, F.R.S.*

This, which is one of the largest ever constructed, has a clear field of $3\frac{1}{4}$ inches in diameter. With a view to saving bulk and weight, the acute angles have been cut off, and the whole reduced to an octagonal form. The advantages of this will readily be seen by comparing this instrument with that by Tisley and Spiller, the field of which is greater by only a quarter of an inch.

873b. A Nicol's Prism for Polarising Light, by Tisley and Spiller. *W. Spottiswoode, F.R.S.*

This, which is the largest and purest ever constructed, has a clear field of fully $3\frac{1}{2}$ inches in diameter.

874. Soleil-Ventzke Polarising Apparatus, with several improvements. *Franz Schmidt and Haensch, Berlin.*

Soleil having introduced compensation by the use of rock-crystal, Ventzke subsequently improved the colour-giving power, and Scheibler made further improvements, principally in the manner of inserting the observation tubes. Messrs. Schmidt and Haensch, besides a few minor changes, succeeded in

making improvements which greatly facilitate the use of the instrument, by a change in the construction of the wedges, and have thus reduced the irregularities frequently observed in the polarisation of bodies of low specific gravities to from one to two tenths of a per cent. in each part of the scale. They have thereby done away with the principal cause of the variations which so frequently occur in the observations of different analysts.

875. Jellett & Corny Half-shade Polarising Apparatus, provided with wedge compensation.
Franz Schmidt and Haensch, Berlin.

This apparatus differs from the foregoing in having the double plate replaced by a double Nicol's prism. In using it both fields of the apparatus are adjusted to equal half darkness, instead of equal colour, as in the "Soleil." The double Nicol prism was first proposed by Professor Yelett, of Dublin, and employed by Professor Corny in Duboscq's polariscope for circular polarisation, known as saccharomètre à pénombre. The improvement in the instrument exhibited by Messrs. Schmidt and Haensch consists in combining with it their wedge-compensation, so as to obtain the advantage of lineal readings. The instrument recommends itself for dark solutions; it is indispensable for colour-blind operators, and it prevents the colour-weariness to which the healthy eye is liable. Its sensitiveness perceptibly exceeds that of a Soleil.

876. A Wild's Polari-Strobometer.
Franz Schmidt and Haensch, Berlin.

877. Jellett-Corny Polarising Apparatus, constructed for circular polarisation. *Franz Schmidt and Haensch, Berlin.*

878. Mica-preparations of mono- and bi-axial mica, for polariscopes. (See Mineralogy.) *Max. Raphael, Breslau.*

879. Mica-preparations of foliaceous mosses ("Laubmoosen"), Algal, &c., for microscopes. *Max. Raphael, Breslau.*

879a. Quartz Axis Plates. *M. Lutz, Paris.*

879b. Amethyst cut parallel to the axis. *M. Lutz, Paris.*

880. Dichroscopic Lens.
Four Nicol's prisms.
One Grazmowski prism.
Two Tourmlines parallel to the axis.
Fluor-spar of M. Bertrand's arrangement.
Quartz and mica for compensating the refraction of crystals.
Heated crystals, felspar, gypsum, carbonate of lead.
One blue glass, red glass, and violet glass.
Laurent.

882. Table Polariscope, made by the contributor when a youth. *Rev. Nicholas Brady, M.A.*

The interest of this instrument consists in showing with what simple materials a student can construct a fairly useful apparatus, the divided circles being common stamped protractors; the clamping screws, teapot thumbscrews, and the mountings of the lenses ordinary simple microscope frames.

882a. Original Apparatus for Rotatory Polarization, by Bit. *College of France, Paris.*

883. Airy's Polariscope, with appliances for approximately measuring the angle between the planes of polarization and analysation, and for determining the angle between the optic axis of biaxial crystals in air or in a fluid medium. Modified and arranged by the contributor when a student. *Rev. Nicholas Brady, M.A.*

883a. Large Polariscope for Projection, by Ladd. *W. Spottiswoode, F.R.S.*

A pair of Nicol's prisms, by Ladd, the first of a large size ever constructed. They are furnished with a system of lenses for showing the crystal rings, as well as with other contrivances for the various phenomena of polarised light.

883b. Revolving Analyser for Polariscope, constructed by Tisley and Spiller. *W. Spottiswoode, F.R.S.*

A revolving analyser, consisting of a double image prism, furnished with wheel-work, whereby it may be caused to revolve with such rapidity that the eccentric image may remain upon the retina during a complete revolution, and thus give the appearance of a ring of light. By this means all the phases of polarised light as seen successively in ordinary polariscopes may be seen simultaneously. The instrument is adapted to show all the phenomena of chromatic polarisation, both plane and circular. An instrument for a similar purpose was invented independently by Prof. Machs, of Vienna.

883c. A portable form of Polariscope, comprising a Nicol's prism, a double-image prism, a plate of tourmalin, a Savart's wedge, a biquartz, and a quarter undulation plate. These various parts may be used either separately or in any combinations at pleasure ; and are consequently adapted either to illustrate the general laws of polarised light, or for actual observations of atmospheric or other polarisation not involving actual measurements. It will be observed that the tourmalin plate gives the opportunity of using convergent as well as parallel light. The size of the instrument might, however, be reduced considerably below the dimensions of the specimen here exhibited. *Mrs. W. Spottiswoode.*

883d. Large Circle for measuring the **Azimuths** of **Elliptic** and **Rotatory Polarization**, and reproducing all experiments of polarization and reflection. *School of Pharmacy, Paris.*

883e. Arago's Polariscope. *M. Lutz, Paris.*

883f. Savart's Polariscope. *M. Lutz, Paris.*

883g. Tourmalin Plates. *M. Lutz, Paris.*

883h. De Sénarmont's Polariscope. *M. Lutz, Paris.*

884. Wheatstone's Polar Clock. To determine the true solar time by the polarisation of light reflected from the sky.

Wheatstone Collection of Physical Apparatus, King's College, London.

885. Latest form of Wheatstone's Polar Clock. To determine the true solar time by the polarisation of light reflected from the sky.

Wheatstone Collection of Physical Apparatus, King's College, London.

886. Polariscope and Set of Crystals.

Prof. W. F. Barrett, Dublin.

887. Norremberg's Polarising Apparatus, with Wheatstone's improvements. *H. Lloyd, Trinity College, Dublin.*

888. Duboscq's Polariscope, for determining the inclination of the axes in biaxial crystals.

H. Lloyd, Trinity College, Dublin.

889. Wheatstone's Apparatus for illustrating the laws of interference of polarised light.

H. Lloyd, Trinity College, Dublin.

III.—PHOTOMETERS.

891. Great Atmospheric Photometer. A De la Rive model, designed by M. Thury, and constructed by the Geneva Association for Constructing Scientific Instruments.

De la Rive Collection. The property of Messrs. Soret, Perrot, and Sarasin, Geneva.

This apparatus is particularly intended to measure the transparency of the atmosphere. It is used for simultaneous observation, with one eye, through two similar reflectors placed at different distances. The difference of brightness and of tint between the two reflexions indicates the effect of the interposing stratum of air. The computation of this difference is arrived at by equalising the two reflexions by means of diaphragms of different aperture, and of glass plates variously tinted. The instrument is composed of a telescope with a single eye-piece, and two objective tubes, of which the angular distance varies at will between 0° and 29°. A system of four full reflecting prisms unites the two divergent cones in the eye-piece. The apparatus is movable round three different axes, and may be worked in the most varied directions. Graduated circles measure these diverse angular motions. It is a general photometer, and can be specially used as an astronomical photometer. De la Rive has effected with it a long series of observations on the transparency of the air. (See Comptes Rendus, vol. 63, p. 1221.)

892. Photometer, according to Glan's system, for photometrical determination of the absorption spectra for homogeneous light. *Schmidt and Haensch, Berlin.*

892a. Photometer, fitted with clock, governor, pressure gauge, and all necessary apparatus complete, as adopted by the Government of Canada. *William Sugg.*

893. Photometer by **Bunsen,** simplified by Professor Bohn.
Physical Collection of the University of Giessen, Professor Buff.

The standard for comparison is a pure stearine candle of known weight. The measure wound upon the cylinder serves to determine the distance at which the oil spot on the paper, when viewed from the second flame, is brought to disappear. First the standard candle, and then the flame, to be measured, are thus investigated. The intensities of the two lights are to one another as the squares of their distances from the oil spot.

894. Photometer, for ascertaining amount of daylight.
Scottish Meteorological Society.

The light is reduced by turning round the graduated milled head at the side, which works simultaneously and by equal degrees the two shades which thus reduce the area of the aperture. At the opposite end of the box a printed page is looked at through the eye-piece till it ceases to be legible, when the result is read off in revolutions of the milled-head. Designed by Thomas Stevenson, C.E., F.R.S.E., Honorary Secretary, and described in Society's Journal, vol. iii., page 292.

895. Selenium Photometer. *Siemens and Halske, Berlin.*

It being the property of selenium that its electrical resistance is diminished by the action of light, the diminution being proportional to the intensity of the light, this apparatus is constructed with a plate of selenium forming part of an electric circuit which is brought by rotating the cylinder containing the plate alternately under the action of a normal candle sliding on a scale and of the light to be measured. The normal light is adjusted on the sliding scale until the electrical resistance of the selenium remains constant under the action of the two sources of light, and the intensity of the light to be measured is calculated from the relative distances of the lights from the selenium plate.

897. First Heliostat, invented by 'sGravesande.
Professor Dr. P. L. Rijke, Leyden.

(*See* 'sGravesande's "Physices Elementa Mathematica," ed. III., Tom. I., page 715.) 'sGravesande was an eminent Dutch geometrician, b. 1688, d. 1742.

898. Heliostat, G. Johnstone Stoney's modification, made by Spencer and Sons, Dublin, a cheap and useful form.
Prof. W. F. Barrett, Royal College of Science for Ireland, Dublin.

IV.—RADIOMETERS.

899. A Collection of Radiometers of different construction, with lamps and screen for making experiments.
Professor Adolph Weinhold, Chemnitz.

The apparatus serves to perform the radiometer's experiments, described by the exhibitor in *Carl's* "Repert. der Experimental Phys., 1876, Heft. 2." Compare also the description annexed to the apparatus.

900. Some new Radiometers. *Dr. H. Geissler, Bonn.*

901. Radiometer. *John Browning.*

These instruments are set in motion by either light or heat; they consist of four small discs on two arms at right angles to each other; the discs may be of pith or mica; those exhibited are made of mica, as they appear to be the most sensitive to minute traces of light. One side of each disc has a dead black surface. The action of light or heat repels the black surfaces, and continuous motion is obtained so long as any light or heat falls on them.

902. The late Prof. T. T. Müller's Apparatus for illustrating the influence of the intensity of light on its rapidity of propagation (Poggendorff's Annalen, 1872, cxlv. p. 86.)
Professor A. Mousson, Zurich.

Use is made of Newton's rings, produced between a plane glass *a*, and another glass *b* (the latter very slightly convex), which may be removed (in a known manner) so as to produce differences of progression up to 50,000 waves. At this distance, the convex glass *b*, on which *a* rested at first, radiates in the centre of a square iron vessel *c* on mercury. The three screws of the support *d* which surrounds the glasses are fixed apart. Then, the mercury having been allowed to flow out (through the cock *b*), *e* is brought down and fixed also, by means of three other screws *y*. The distance can be calculated with great precision by means of the weight of the mercury, and the known area of the vessel *c*.

The luminous point used is the small image at the opening of a collimating tube *e*, lighted by a flame ("flamme de Soude"), upon the hypothenuse surface of a small prism *f*. From this point the rays diverge and fall on the lens *g*, placed on the glass *c*, which makes them parallel. These rays return, with interference, from the two reflecting faces, towards the point *f*, where the eye is placed close to the prism.

Now, if the intensity of the light be lessened by interposing absorbing glasses, it will be seen that the greater the difference in the number of waves the more the lines change place, the increase of rapidity being proportionate to that of intensity.

V.—REFLECTION, REFRACTION, AND DIFFRACTION.

903. Total Reflection Apparatus, for the projection of objects placed in a horizontal position.
T. and A. Molteni, Paris.

904. Small Prism for double reflection. *Laurent.*

905. Coloured Rings on an 80 millimetre tripod.
Laurent.

905a. Fresnel's Parallelopiped. *M. Lutz, Paris.*

908. Apparatus designed to exhibit Double Reflection, which arises when a ray of light traversing a uni-axial or bi-axial crystal reaches the surface of contact of the crystal with the surrounding medium. *Arthur Hill Curtis.*

The incident light passes through a small orifice in the cap terminating one of the tubes. If the eye be applied to the other tube, as the stage on which the crystal rests is turned round its vertical axis, four, three, or two images of the orifice will be seen formed by the two rays which, refracted at the upper surface, are (in general) *each* doubly reflected at the lower surface. A Nicol's prism is added, which, though not essential to viewing the phenomena, may be introduced into *either* tube to polarise the incident light, or to examine the planes of polarisation of the reflected rays.

908a. A large Mass of Iceland Spar, polished to exhibit the optical properties of the crystal in directions parallel and perpendicular to the optic axis, and in directions perpendicular to the cleavage plane 100, and to the plane 122 correlative with it. Worked and polished by Mr. Ahrens.
Professor N. I. Maskelyne, F.R.S.

909. Extra Dense Flint Prism, of 60°, surface 4 by 3 in.
A. Hilger.

910. Iceland-spar Prism, of 60°, showing single refraction for any line in the spectrum. *A. Hilger.*

911. Prism, with Double Reflector, of Dr. de Wecker. Two triangular prisms are joined together at their hypothenuse; while the direct observer looks through the cube formed by the union of the two prisms, an incidental observer sees in the hypothenuse the same reflection as though in a mirror. The 2¼ lens serves to show the reflection smaller and reversed.
M. Crétès, Paris.

912. Prism, Moveable, by Crétès. Two prisms of 15° each are placed in a setting. When placed basis on edge, their refraction becomes annulled: ($15-15=0$). When placed basis upon basis, their effect becomes added: ($15+15=30$). Between these two extremes, an ascending scale of 0 to 30° can be obtained. The prismatic axis remains fixed, because the glasses move in reverse ways and in equal volume. *M. Crétès, Paris.*

912a. Three Rectangular Prisms, crown glass.
M. Lutz, Paris.

912b. 32 Rectangular Prisms, flint glass of various sizes.
M. Lutz, Paris.

912c. Prisms for Camera. *M. Lutz, Paris.*

912d. Prisms with Compartments. *M. Lutz, Paris.*

912e. Prisms with Compartments. *M. Lutz, Paris.*

912f. Bi-refracting Spar Prisms. *M. Lutz, Paris.*

912g. Rhomboids of Spar. *M. Lutz, Paris.*

912h. Collection of 12 Nicol Prisms. *M. Lutz, Paris.*

912i. Four Large Nicol Prisms. *M. Lutz, Paris.*

912j. Prisms for M. Desain's Experiments.
M. Lutz, Paris.

912k. Uranium Glass Prisms. *M. Lutz, Paris.*

912l. Uranium Glass Cube. *M. Lutz, Paris.*

912m. Three Quartz Prisms. *M. Lutz, Paris.*

912n. Six Prisms for Spectroscope (direct light).
M. Lutz, Paris.

912o. Six Prisms for Spectroscope (direct light).
M. Lutz, Paris.

912p. Two Pyramidal Prisms. *M. Lutz, Paris.*

912q. Three Flagon Prisms. *M. Lutz, Paris.*

912r. Four Poly Prisms. *M. Lutz, Paris.*

912s. Four Prisms for Bisulphide of Carbon.
M. Lutz, Paris.

912t. Two Isosceles Prisms of Flint Glass.
M. Lutz, Paris.

912u. Three Foucault's Prisms. *M. Lutz, Paris.*

912v. Two De Sénamont's Prisms. *M. Lutz, Paris.*

912w. Three Braszinowski and Hartnack's Prisms.
M. Lutz, Paris.

912x. Six Rochon's Prisms. *M. Lutz, Paris.*

912y. Boit's Prism. *M. Lutz, Paris.*

912z. Large Flint Glass Prism, extra denticulated, set in a peculiar manner. *M. Lutz, Paris.*

913. Instrument to show the phenomenon of conical refraction, with models of Fresnel's wave surface. (Soleil, Paris.)
H. Lloyd, Trinity College, Dublin.

914. Jamin's Optical Bank of Diffraction.
H. Lloyd, Trinity College, Dublin.

914a. Jamin's Apparatus with Parallel Mirrors.
M. Lutz, Paris.

914b. Large Steel Mirror. *M. Lutz, Paris.*

914c. A Series of Barton's Iris Buttons, consisting of gold and steel faces engraved upon which are numbers of very fine lines, illustrating most beautifully *iridescence* or decomposition of light from grooved surfaces. The lines on the large steel button are 100, 200, 400, 500, 1,000, 2,000, and 4,000 to the inch.
Robert C. Murray, London.

915. Optical Bank, improved by Professor Clifton, of Oxford, to observe the interference and diffraction of light and measure the bands. *Elliott Brothers.*

915a. Photographed Diffraction Gratings, the originals by Nobert, 6,000 and 3,000 lines in a square inch.
Lord Rayleigh.

For description see accompanying pamphlet, from Philosophical Magazine.

915b. Collection of Six Gratings (*réseaux*) by Nobert in Barth, and Steig in Homburg. *Foundation Teyler at Haarlem.*

Nobert	B. of	1,801	grooves	on six Paris lines.
„	C. of	3,001	„	„ „
„	D. of	10,801	„	on one Paris inch.
„	E. of	2,001	„	„ „
„	F. of	3,001	„	„ „

Steig A. of 3,201 grooves on five millimètres.

Nobert B and C were used by Prof. Van der Ur'lligen for the determination of the wave-lengths of fifty lines in the solar spectrum.

915c. Specimens of circular **Gratings** (*Réseaux*) photographed on **Glass.** The rays of the successive circles limiting the opaque and transparent parts are in the proportion of 1 to $\sqrt{2}$, $\sqrt{3}$, $\sqrt{4}$, $\sqrt{5}$, &c.

915d. Large **Grating** (*Réseau*) on **smoked Glass,** transparent traces of equal width, having rays in the proportion of $\sqrt{3}$, $\sqrt{7}$, $\sqrt{11}$, $\sqrt{15}$, $\sqrt{19}$, &c. *J. Louis Soret, Geneva.*

See "Mémoire sur les Phénomènes de Diffraction produits par les Réseaux circulaires" (Archives des Sciences physiques et naturelles, 1875, Vol. 52, p. 320. Poggendorff's Annalen, 1875, No. 9).

915e. Telescope for Circular Gratings (*Réseaux*). Constructed by the Geneva Association for Constructing Scientific Instruments. *J. Louis Soret, Geneva.*

1st arrangement. For objective, the réseau on smoked glass is used, and for the eye-piece, a common eye-piece. Looking at a jet of gas (for instance) at seven metres distance, the deviation of the objective and the eye-piece being from 34 to 41 centimetres (pull one of the tubes), the reflection of the jet is seen reversed, and coloured more or less. By shortening the glass as much as possible, the second reflection is seen green-coloured.

2nd arrangement. A common objective is used, and for eye-piece, the small photographic réseau. The deviation from the objective to the eye-piece being of 50 centimetres (maximum width of the telescope), the reflection of the gas jet, reversed, is obtained as in an astronomical glass. By shortening the glass to 31 centimetres, the direct reflection is got as in the Galileo telescope. (*See* Mémoire sur les Phénomènes de Diffraction produits par les Réseaux circulaires, Archives des Sciences physiques et naturelles, 1875, vol. 52, p. 320.)

916. Refractometer, according to **Abbé's** system, for determining the refractive indices, and the dispersion of any kind of liquids. *Carl Zeiss, Jena.*

The refractometer enables one to determine the refraction index of a liquid with a single drop of the substance up to four decimals. The indications refer to line D, and are directly read off from a graduated sector.

917. Procentum Refractometer, for determining the percentage of solutions and mixtures by optical means.

Carl Zeiss, Jena.

The instrument is designed for liquids whose index lies between 1·3 and 1·4. The determination takes place at a numbered scale in the field of view of a small telescope. Besides the scale for the absolute index of refraction, there is another scale, which gives directly the per-centage strength of saccharine liquor.

917a. Refractometer by M. Jamin.

Polytechnic School, Paris.

917b. Jamin's Interferential Apparatus with two Spars. *M. Lutz.*

917c. Refraction Goniometer, constructed by the Rev. Baden Powell, and used in some of his experiments, and afterwards by the Rev. T. Pelham Dale and Dr. Gladstone in their earlier researches on refractive indices of liquids at different temperatures. *Mrs. Baden Powell.*

918. Apparatus for demonstrating the **Refraction of Light** in liquids, according to J. Müller.

J. Wilhelm Albert, Frankfort-on-Maine.

The semicircular plate of the refraction apparatus is of glass, ground on its outside and having the scale burnt into it in black. The ray refracted from the liquid appears therefore on the outside of the graduated plate and can thus be viewed by larger audiences.

919. Abbé's Refractometer, for determining the power of refraction of different liquids as far as the fifth decimal, with direct

reading of the refractive index, without calculation. (Comp. Abbé: "Neue Apparate.")

Franz Schmidt and Haensch, Berlin.

920. The same, smaller model.

Franz Schmidt and Haensch, Berlin.

921. Apparatus, according to J. Müller's principles, **for experiments as to the refraction of rays of light in fluids,** all of glass. *Warmbrunn, Quilitz, and Co., Berlin.*

921a. Apparatus by M. Mascart for studying the refraction of gas. *M. Mascart, Professor at the College of France.*

921b. Apparatus for determining the Refraction Index of Solids and Liquids.

C. Czechovicz, teacher of Physics at the Gymnasium of Belostok, Russia.

Consists of a horizontal board and vertical divided pillar with movable support for a telescope. The body under examination is put on a glass plane attached over a slit in the board, through which a light beam is reflected by an inclined mirror. A linear mark made on the upper surface of the glass (if the body is solid), or on the upper surface of the vessel (if the body is liquid), is brought in coincidence with a movable wire which touches the upper plane of the body. The distance of this wire and the height and inclination of the telescope give the necessary data for calculating the index with sufficient approximation.

VI.—FLUORESCENT BODIES.

922. Fluids showing the **Phenomenon** of **Fluorescence.**

Charles Horner.

A. Soda salt of anthracene in water.
B. Fluorescine in water.
C. Eosine in water.

923. Fluids showing the **Phenomenon** of **Fluorescence.**

Charles Horner.

Small Tubes in Stand.

D. Turmeric in castor oil.
E. Harmaline in water.
F. Magdala red in alcohol.
G. Ebony wood (*Amerimuum ebenus*) in castor oil.
H. Inuline in chloroform.
I. Esculine in water.
K. Camwood (*Baphia nitida*) in castor oil.
L. Esculetine in water with alkali.
M. Fraxine (*Fraxinus excelsior*) in water.
N. Fustic (*Maclura tinctoria*) in solution of alum.

924. A selection of eight fluorescent liquids.
Dr. Th. Schuchardt, Görlitz.

VII.—PHOTOGRAPHY.

a. Photographic Processes.

925. Frame containing glass negative, gelatine "relief," leaden "mould," and impression from the latter, showing the various stages in the production of a "Woodbury" permanent photograph.
Woodbury Permanent Photographic Printing Company.

926. Frame containing transparencies for the magic lantern, printed by the "Woodbury" process.
Woodbury Permanent Photographic Printing Company.

927. Specimens of Willis's Aniline Process. Printed from tracings by Vincent Brooks, Day and Son.
William Willis, Bromley, Kent.

This is a method of photographic printing differing greatly from all other kinds in the chemical actions involved and in the manipulations required. The blacks of the picture are produced by the action of aniline vapour on free chromic acid; the paper having been first coated with the latter substance, and exposed to light under the drawing to be copied. On placing this exposed sheet in a chamber filled with aniline vapour the yellow unaltered chromic acid becomes speedily blackened, and produces a permanent print. No negative is required, but a positive print is obtained by one operation from a positive original. The principal application of the process is the copying of engineers' and architects' tracings.

928. Willis's Platinum Printing Process.
Wm. Willis, jun., Birmingham.

This is a method of photographic printing by which the picture is made to consist of platinum black instead of silver. The reduction of the platinum salt, with which the paper is coated, is effected by the action of light on a persalt of iron, which forms an additional coating to the paper, followed by a floating of the print on a solution of potassic oxalate.

928a. Illustrations of the Heliotype Process.
J. B. Edwards and Co.

The photographs are printed in printers' ink, at an ordinary printing press, from a film of gelatine, whereon the photographic image has been imprinted by the action of light.

1. A gelatine film ready for exposure to light under the negative.
2. A film laid down upon a metal plate and inked up ready for printing from.
3. A proof in permanent ink from the same film.

928b. Photograph Reproductions.

1. Embroidered stuff on velvet ground.
2. Faience dish, after Bernard Palissy.
3. Blue framed enamel, pâte tendre de Solon.
4. Louis XIV. shield, repoussé copper.
5. Incense-burners, silver filigree, enamel and stones.
6. Mirror, silver-gilt and precious stones.
7. Tobacco jar, gold and silver.
8. Holy-water vessel, Limoges enamel, with frame and precious stones.
9. Hunting knife handle, silver and stones.
10. Byzantine dish, repoussé copper.
11. Aliotide shell, from nature.
12. Cup, silver and rubies.
13. "The First Fable," after the oil painting by Simonetti (Salon de 1875).
14. "After Action," after the oil painting by Marchetti (Salon de 1875). *M. Léon Vidal, Paris.*

928c. Specimens of Dallastype. *D. C. Dallas.*

928d. Specimens of Dallastint. *D. C. Dallas.*

928e. Specimens of Chomo Dallastint. *D. C. Dallas.*

928f. Specimens of Carbon transparencies.
Col. Stuart-Wortley.

928g. "Cleopatra," a solar enlargement on salted paper, by R. Fenton, from a photograph of the original in the National Gallery. *Robert Sabine, Regent's Park.*

928h. Seven Photographic Prints on Salted Paper, from Waxed Paper Negatives.

Two views of Windmill for reflecting stereoscope, by B. B. Turner.

Two views of the First Post on the road from Kief to Moscow by R. Fenton, for reflecting stereoscope.

Two views of a Russian Cottage, for reflecting stereoscope, by R. Fenton.

View of ruined Interior, by Le Gray.
Robert Sabine, Regent's Park.

928j. Two Sheets of Photographic Prints, by the Iron and Uranium process. M. Nièpce de St. Victor, 1857.
Robert Sabine, Regent's Park.

928k. Five Sheets of Photographic Prints, from waxed paper negatives on albumenized paper, by R. Fenton.
Robert Sabine, Regent's Park.

928l. Ten Photographic Prints from waxed paper negatives on albumenized paper, 1853.

Robert Sabine, Regent's Park.

928m. Two Sheets of Talbotype Prints from waxed paper negatives. *Robert Sabine, Regent's Park.*

928n. Two Views for the Reflecting Stereoscope; the varnish used to render the prints transparent, having preserved the details of image from fading. *Robert Sabine, Regent's Park.*

929. Specimens of Dujardin's photo-engraving process.

Dujardin, Paris.

930. Specimens of Photo-type Printing on Zinc.

Capt. Abney, R.E.

930a. Photo-engraving of a Group of Sun Spots.

W. de la Rue, F.R.S.

931. Gillot's Photo-type Process. *Veuve Gillot.*

932. First known Photograph on Glass, taken on precipitated silver chloride, by Sir J. Herschel.

Professor A. Herschel.

"Having precipitated muriate of silver in a very delicately divided state from water very slightly muriated it was allowed to settle on a glass plate; after 48 hours it had formed a film thin enough to bear drawing the water off very slowly by a siphon, and drying. Having dried it I found that it was very little affected by light, but with washing with weak nitrate of silver and drying it became highly sensible. In this state I took a camera picture of the telescope on it. Hypomess. soda then poured cautiously down washes away the muriate of silver, and leaves a beautiful delicate film of silver representing the picture. If then the other side of the glass be smoked and black varnished the effect is much resembling daguerreotype, being dark on white as in nature, and also right and left as in nature, and as if on polished silver."—*Sir J. Herschel.*

933. Second Daguerreotype, obtained by Daguerre in 1839. Lithographic stone of Poiteven, with a proof on paper.

Conservatoire des Arts et Métiers, Paris.

935. Photographs by Daguerre. *M. Fizeau, Paris.*

937. Specimens illustrating the History of Photography. *French Photographic Society, Paris.*

937a. A Daguerreotype full-length Portrait, taken in Paris in **1840,** by special appointment, on the roof of a house in the open air, at 6 a.m. Exposure 20 minutes! in June sun.

James Martin.

937b. Original Book of Experiments made by **Sir J. Herschel** on the **Metallic Salts** sensitive to **Light.**

Professor A. Herschel.

938. An Instantaneous Photograph. Waves breaking on the shore of Britain in 1876. *James Martin.*

939. Engraving with the Aid of Photography. *MM. Goupil et Cie., Paris.*

Proofs obtained by impression with fatty ink on copper plates engraved by hand, the lines on which are obtained by means of a photographic negative, with the use of chemical substances sensitive to the action of light.

1. "Pollice verso," after the painting by Gérôme.
2. "L'eminence grise," do. do.
3. "Rembrant dans son atelier" (Rembrant in his studio), after the painting by Gérôme.
4. "Il Décamerone" (The Decameron), Sorbi.
5. "La rentrée au Convent" (The return to the Convent), Zamacois.
6. "Le premier coup de canon" (The first cannon shot), Berne, Bellewurt.
7. Part of the colonnade of the Louvre, from nature.
8. Reproduction of a mineralogical fragment, from nature.
9. Frame containing the two plates from which proofs Nos. 7 and 8 were printed.

940. Thiel Ainé Pantotype (modification of the Albertype process). *Thiel Ainé, Paris.*

943. Photo-lithography Process of Simonan and Toovey. *Veuve Simonan and Toovey.*

1. Plan of the town of Liège.
2. Portrait of Archbishop St. Lambert, after an old engraving.

3–7. Topographical plans, photographed by Capt. Hanot.
8–13. Six drawings of the "Campagnie des bronzes" at Bruxelles.
14–15. Two reproductions from a line drawing by Licot de Nivelles.
16–19. Four archæological drawings.
20. Frontispiece of an ancient MS.

This is a photo-lithographic process, and depends on the fact that if gum be mixed with potassium dichromate, and when dry be exposed to the action of light, it becomes insoluble. A paper is coated with gum and potassium dichromate, and exposed under the negative of a line subject, or under an etching on glass, having a non-actinic ground. When light has sufficiently acted, the paper which has a faint impression of the lines is placed under a pile of damped paper on the surface of a polished lithographic stone, and submitted to pressure for about an hour. The paper is then removed from the surface of the stone, the insoluble part forming the lines leaving with it. The lines of the engraving are thus left ungummed on the stone. A little olive oil is brushed over the surface, when the gum on the stone has been allowed to dry in a dark room. The surface is next washed, which dissolves away the gum, leaving the lines of the picture formed of only matter. The stone is then rolled up with a lithographic roller, and is ready for giving impressions.

944. Specimens of Paul Pretsch's Photo-typography. *Warren De La Rue, F.R.S.*

945. Electro-chemical Process for reproducing on copper lithographic impressions. *M. Erhard.*

A proof freshly pulled from an autograph, from a lithograph, from an autolithograph, or from a copper-plate which is intended to be reproduced, is, by this process, transferred to a copper-plate, and furnishes in a few minutes an intaglio copy of the plate, as clean and good as the original, which is in no wise injured by the operation.

By means of this process : firstly, it is unnecessary to preserve the cumbrous and fragile lithographic stones ; secondly, a plate in use may be reproduced so as to ensure repeated impressions ; thirdly, corrections may be made on the copper, which could not be made on the original worn plate, exhausted by repeated workings. The cost of reproduction on copper by Erhard's process is infinitesimally small, and may be calculated at about 3 to 5 centimes per square centimetre.

1. Album containing 36 maps and plans reproduced by this electro-chemical process.

2. 10 copper plates obtained by this process, the impressions from which are shown in the album.

946. Photoglyphic engravings, 1853.
H. Fox Talbot, F.R.S.

947. Silver prints of views in **Knoll Park.**
School of Military Engineering, Chatham.

947a. Proof by Papyrotype Process.
School of Military Engineering, Chatham.

947b. Specimens of Enlarging Process.
School of Military Engineering, Chatham.

948. Second Proof of Photographic Engraving, obtained by M. Fizeau, without retouching, in 1843, and printed in greasy ink. *M. Fizeau, Paris.*

949. Daguerreotype Proof, fixed by M. Fizeau's process with chloride of gold, by Mr. Hubert, in 1840. *M. Fizeau, Paris.*

949a. Daguerrean Print, obtained by the continuous action of red rays, without mercury. *M. E. Becquerel.*

950. Photochromic Proofs (selection). *M. Vidal, Paris.*

951. Early Talbotypes.
Museum of Physical Apparatus, King's College, London.

951a. Enamel Process, Specimens of.
Wm. Mayland.

952. Table of Specimens of Historical Records of Photography. *French Photographic Society.*

952a. Photography in its Application for Cartographical Purposes.
The Topographical Department of the Imperial Russian General Staff at St. Petersburg.

At the application of the negative process, Rupell's drying system, with tannin, has been employed. The positive prints are either black silver copies or blue iron pictures, to which preference is given in case the photograph is to be traced over with Indian ink, and the photographical ground to be removed afterwards by etching for the purpose of producing a clean drawing.

1. Reproductions of Central Asiatic surveys and maps.
2. Copies of surveying plate sheets in European Russia.

952b. Photolithography.

The Topographical Department of the Imperial Russian General Staff at St. Petersburg.

Transfer on stone of a printable picture, well covered with ink, which has been produced on a gelatine ground rendered primarily sensible by double chromate of potash.

Reproduction of a Hebrew manuscript of the 10th century, belonging to the Imperial Russian Public Library.

952c. Helio-Engraving. Sediment of galvanic copper on a photographical gelatine relief.

The Topographical Department of the Imperial Russian General Staff at St. Petersburg.

Copies of a heliographical edition of the survey of Bessarabia, on the scales of 1 : 100,000, and 1 : 126,000, and the survey of Finnland, scale, 1 : 42,000; map of Khiva, scale, 1 : 580,000, transferred on stone, and prepared as colour print.

952d. Examples of Heliographic and other Processes.

Imperial Establishment for the preparation of official papers, St. Petersburg.

1. Portfolio of heliographic copper-plate and mezzo-tint engravings by the process of G. Scamoni (manager of the Heliographic Department of the Establishment), containing:—
   - 27 reproductions of historical portraits;
   - 10 reproductions of fine engravings;
   - 12 reproductions of etchings;
   - 8 reproductions of drawings executed with pen and ink, water-colour, and crayon;
   - 17 reproductions of pen and ink drawings;
   - 6 reproductions of wood engravings.
2. One heliographic plate in electrotyped copper.
3. One heliographic plate in electrotyped iron.
4. One typographic printing form in electrotyped iron, from type.
5. One typographic printing form in electrotyped iron, net-work from type.
6. One typographic printing form in electrotyped iron, net-work from relief.
7. One typographic printing form in electrotyped iron, guilloched net-work.
8. One typographic printing form in electrotyped iron, id-annealed.
9. A glass plate, with the surface irregularly broken up into floral and other forms through a coating of gelatine (½ millimeter thick), springing up from it when dried at a temperature of about 70° C., thereby producing a form, from which an inimitable printing-plate can be made.
10. Handbook of heliography, by G. Scamoni.

b. PHOTOGRAPHIC APPARATUS.

953. Photographic Lenses for Landscape, Architecture, and Copying, showing progressive improvements from the original single meniscus lens:—

(*a.*) Single meniscus lens, used from 1851 to 1861.
(*b.*) Triplet, consisting of front combination. Double convex crown and plane concave flint; middle combination. Double convex crown and double concave flint; back combination. Double concave flint, and double convex crown. Used from 1861 to 1864.
(*c.*) Doublet, consisting of front combination. Double convex crown and double convex flint; back combination, meniscus crown and concavo-convex flint. Used from 1864 to 1874.
(*d.*) Symmetrical lens, introduced in 1874, and consisting of front combination, Concavo-convex and meniscus lenses; back combination, exactly similar, the denser element being on the outside in both cases. *Ross & Co.*

954. Photographic Lenses for Portraiture, showing the progressive improvements from 1839 to present date:—

(*a.*) Original compound portrait lens. The first lens made in England by Andrew Ross for daguerreotype portraiture in 1839.
(*b.*) Compound portrait lens, with Waterhouse diaphragms, in front. Date 1851.
(*c.*) Compound portrait lens, with Waterhouse diaphragms, giving a flat field. Date 1858.
(*d.*) Compound portrait and group lens, giving a flat field, and straight marginal lines. Date 1874. *Ross & Co.*

954a. New Tourists' Photographic Apparatus for taking Wet Plates without the use of Dark Tent, all baths and chemicals being placed in water-tight compartments under body of camera. *Harvey, Reynolds, and Company.*

955. Photographic Apparatus. "Poor man's photography," for wet collodion negatives of the smallest possible size, but rapid and well defined. Twelve examples of negatives, 1 inch square, two framed and magnified positive copies, and the bath-holder in which these negatives were taken.

Prof. Piazzi Smyth, Royal Observatory, Edinburgh.

These negatives are on microscope slide glasses, and were taken with a lens of rather less than 2 inch solar focus by Professor Piazzi Smyth, in Egypt, in 1865. They represent scenes inside the Great Pyramid by magnesium light, and outside it by daylight, including, in one of them, camels in motion. The two positive copies on glass, each 10 in. high, are exhibited to show to what

extent magnifying may be carried without definition being lost to any sensible degree.

The peculiar bath-holder in which the small negatives were taken is also shown. It has been described in the "British Journal of Photography," in 1866, with improvements in the almanacs of the same journal for 1874 and 1876.

955a. Photographic Apparatus, by M. A. Chevalier, for plan-drawing. *M. J. Duboscq, Paris.*

956. Lichtpaus Apparatus, for photographing maps, plans, &c. *Romain Talbot, Berlin.*

957. Press used in printing a "Woodbury" permanent photograph, with leaden mould imposition.
Woodbury Permanent Photographic Printing Company.

958. Photographic Portrait Objective D.
Voigtländer and Son (Chevalier von Voigtländer), Brunswick.

958a. The same, No. 3.
Voigtländer and Son (Chevalier von Voigtländer), Brunswick.

959. Photographic Lens for Astronomical Photography. *John Henry Dallmeyer.*

A double combination lens (rapid rectilinear) of 4″ diameter and 30″ focal length, consisting of two symmetrical combinations, each having a focus of 63″, and composed respectively of a crown and flint-glass lens, united by a permanently transparent cement to avoid reflections at the contact surfaces. The flint lens occupies the exterior position in each combination. It is concavo-convex, convex sides external. The crown lens is a meniscus, the convex side of the same radius of curvature as the flint lens, and they are cemented.

The radii of curvatures are so apportioned between the lenses that the spherical and chromatic aberrations are destroyed, or, in other words, the combination is aplanatic, and this for an aperture $= \frac{f}{75}$ to $\frac{f}{8}$.

The lens described (one of a series) was constructed and used for photographing the sun's corona.

959a. Photographic Lens for Self-Recording Instruments, *i.e.*, Barographs, Thermographs, &c.
John Henry Dallmeyer.

A double combination lens (No. 2 C) of $2\frac{3}{4}$″ diameter and $4\frac{1}{2}$″ focus. Consists of a cemented front and an open back-combination, having a very large angular aperture, *i.e.*, possessing great intensity. The front or cemented combination is composed of a double convex crown lens, of unequal curvatures, the shallow side occupying the outer position; and the flint lens, a double concave, is united to the deep side of the crown, the adjacent surfaces being identical. At an interval equal to the diameter of the front is positioned the back combination, composed of a flint lens concavo-convex, convex side facing the front combination, and a crown lens nearly plano-convex, or a crossed lens, with the more convex side nearest the flint lens, but of different radii of curvature, and therefore not cemented.

The rati of foci between the front and back combinations are in the proportion of 2·3 nearly, and the radii of curvatures are calculated to produce well defined images for aperture $=\frac{f}{2}$, and angle of picture = 30°.

959b. Photographic Lenses for the reproduction of maps, plans, &c., as practised at the Home and Foreign Government Topographical Establishments. *Joseph Henry Dallmeyer.*

1. A triple achromatic lens of 18″ focal length for copying on plates 15 × 12. As its name implies, this lens consists of three achromatic, or actinic-combinations, two of which, *i.e.* the front and back are positive or converging lenses, and between these two is positioned a negative or diverging lens. The positive combinations, the front of 2″ and the back of 3″ diameter respectively, with focal lengths of similar proportion, are composed each of a double convex crown and a plano-concave flint-glass lens; the adjacent surfaces are identical and cemented. The convex or crown lenses occupy the external position in both, and the combinations are separated by an interval equal to the diameter of the largest or posterior lens. Between the two, and proportionate to their diameters or foci, is placed the diaphragm aperture or stop; this is also the position of the negative achromatic combination 1½″ diameter, the crown of which is in this case a double concave, and the flint a plano-convex nearly. This combination limits the aperture to $\frac{f}{10}$; it does not affect the *direction* of the pencils as refracted by the front and back positive combinations, which produce an image free from distortion, though too much curved to admit of its reception on a flat screen; but its action (that of central pencils only) is confined to the proportionately greater prolongation of the oblique or marginal pencils, in virtue of its negative or divergent power, or, in other words, it lengthens these pencils and produces the required amount of flatness of field, the *sine quâ non* for copying purposes.

This lens, one of a series, was introduced in 1860, and is reported upon by the jurors of the International Exhibition of 1862: "As the first aplanatic "non-distorting view lens placed within the reach of photographers, and the "best lens extant for copying purposes, &c." It was first used in the Ordnance Survey Office at Southampton.

2. A 3″ symmetrical combination of 24″ focal length for plates 18″ × 16″. This lens, constructed for copying, consists of two combinations identical in all respects; each has a focal length of 46″, and is composed of a convexo-concave flint, and a convexo-concave or meniscus crown-glass lens; the radii of curvatures of the concave of the one and the convex of the other are identical and they are cemented.

The combinations, with their convex or flint elements external, are mounted in a tube a given distance apart, in this case about ⅐ of the compound focal length, and midway between them is the perforation for the insertion of diaphragms or stops. Both combinations being identical in form and focal length the directions of the finally emergent pencils are parallel to the incident ones; hence the lens produces images free from distortion.

Flatness of field and correction of aberrations are obtained, for the particular kind of glass employed, by the forms and foci of the component elements, and in order to suit particular requirements the construction is modified for varying angular apertures of from $\frac{f}{4}$ to $\frac{f}{10}$, including proportionate angles of pictures of from 35° to 90°. This lens was introduced in 1866.

960. Photographic Lenses for Portraits and Views.
Joseph Henry Dallmeyer.

1. & 2. These portrait lenses, introduced in 1866, are constructed on a new formulæ, as compared with the first portrait lens, the invention of Professor Petzval of Vienna, and which appeared in 1841.

Unlike the lenses used for astronomical photography, copying, &c., required to produce a sharp image of an object situated in *one* plane necessitating perfect correction for aberration, a portrait lens must produce a presentable picture of the human face, head, and body, situated in *different* planes; or possess what is called "depth of focus." A *perfectly corrected lens*, of sufficient angular aperture or rapidity of action to make portraiture possible, has no "depth of focus." An instrument, possessing a certain residual amount of spherical aberration, solves the difficulty to some extent. Unfortunately, however, a lens so constructed works at its best only for a given size of image or distance of object. If this be removed to a greater distance, as for a smaller image, the aberration is in excess, and if placed nearer the converse obtains.

The lens now to be described surmounts this difficulty. Its aberrations, both spherical and chromatic, are perfectly corrected when used intact, or as sent out by the maker; and by the simple turn of a screw, or separation of the component elements of the posterior combination, this correction can be modified at will, *i.e.* positive spherical aberration, or "depth of focus," is obtained, proportionate in amount to the separation of posterior lenses.

The front combination, composed of a double convex crown, and a double concave flint glass lens, is cemented, to prevent loss of light from reflections. The convex or crown lens occupies the exterior position. At a distance equal to the diameter of the front is positioned the back combination; an uncemented compound of the same diameter as the front, but of greater focal length, *i.e.* as 2 : 3. The crown element of the back combination is a meniscus with its concave surface facing the front combination. The flint is a concavo-convex, the convex side external; this lens is mounted in a cell, the screw of which affords the means of approach to, or separation from, the companion crown lens. An index and division registers the amount.

The converging cone of rays refracted by the front is incident upon the crown element of the back combination; on emergence it is more strongly convergent when it meets the concave surface of the posterior flint lens. It is evident that any alteration in position or distance at once reduces or increases its effective diameter, or, in other words, its aberration $=y^2$. The aberrations being perfectly corrected when the posterior flint lens is screwed home, or the index pointing zero, the smallest amount of unscrewing or increased separation at once introduces positive spherical aberration.

In Petzval's lens the position of the lenses composing the back combination is the reverse of the above; the flint, a convexo-concave element, faces the front combination, the rays when refracted by it are parallel or nearly so, and any alteration of distance of the companion crown lens is without effect upon the state of aberration of the objective as a whole.

The portrait lens constructed on the new formulæ is free from disturbing reflex images; it produces pictures approximately free from distortion, and illuminates a larger angle of field. It is made of three descriptions: the A series, aperture $=\frac{f}{4}$, B$=\frac{f}{3}$, and D $=\frac{f}{6}$.

3. A single combination landscape lens of 2″ diameter and 12″ focal length for pictures on plates 12 × 10″. It is composed of three lenses, two of which are of crown glass of different optical properties, and between these two is the correcting flint glass lens. The crown lenses are deep menisci, ratio of foci of front to back as 1 : 3; the flint is a concavo-convex. The adjacent surfaces of crowns and flint being identical they are cemented, and externally the combination is a deep concavo-convex, the concave facing the view or

landscape Its aperture is limited by a diaphragm plate placed at a distance of $\frac{1}{7}$ its focal length in front of the lens; the stops provide apertures from $\frac{f}{1}$ to $\frac{f}{40}$. Correction of chromatic spherical aberration is obtained by the foci and forms of the lenses employed.

The angle included extends to upwards of 70°, and though marginal distortion of image is not entirely avoided, it is perhaps counterbalanced by the increased brilliancy of image and equality of illumination, due to the absence of all disturbing or reflex images.

4. A wide angle rectilinear lens of $1\frac{1}{2}''$ diamter, and $7''$ equivalent focal length for 12 × 10 pictures.

This lens is constructed upon the same general principle as the symmetrical $3''$ combination already described, with this difference, that the lenses composing it, though of similar forms, are of proportionately smaller diameter, *i.e.*, they are thinner, and being placed nearer together, they transmit more oblique pencils, or a larger angle of picture is included, as much as 90°, with apertures $\frac{f}{10}$ to $\frac{f}{40}$.

This instrument is designed for photographing objects in confined situations, such as interiors of buildings, monuments, &c., where the camera cannot be removed to a greater distance. It produces images free from distortion.

962. Apparatus for producing pictures in permanent pigments.

The Autotype Process.

If a negative in half-tones be placed under a paper coated with gelatine pigments of any kind and potassium dichromate, and then be exposed to light, the action that takes place is, the gelatinous film is rendered insoluble, and depths varying according to the intensity of the light passing through the various portions of the negative. If the paper were at this stage exposed to the action of hot water, it would be found that the soluble portions lay between the exterior surface of the film and the inner surface of the paper. In order to develop the picture, it is transferred by simple atmospheric pressure to a zinc plate or other temporary and impervious support. The original paper peels off, and the development takes place by the simple application of hot water, the shades of the image being formed of different thickness of gelatine and pigment. The image may be retransferred from the temporary support, or if developed on a paper support may be left as it is, in which case, unless the negative be reversed, the picture will appear reversed.

962a. Apparatus for producing photographs in permanent pigments; consisting of,—

Registering pressure frame.

Plates of zinc, porcelain and opal glass (the plates having upon them: *a.* The sensitive tissue ready for development. *b.* The supporting paper stripped off. *c.* The picture partly developed. *d.* The picture ready for transfer).

Reservoir for hot water, with means of keeping it warm, and grooves for the plates.

Zinc tray for development washing, &c.

Wooden stool and squeezer for the mounting of the exposed sensitive tissue. *The Autotype Company.*

962b. Actinometers, or instruments for ascertaining the intensity of the action of the light, and by which the exposure of the sensitive pigment paper under the negative is regulated.

Johnson's, Vogel's, Spencer's, Lambert's, Sawyer's, Burton's, Vidal's. *The Autotype Company.*

Chemicals Employed.

Granulated bichromate of potash. Chrome alum.

Colours.

Indian ink, vegetable black, Paris black, plumbago, Indian red, Venetian red, vermillion, purple madder, brown madder. vandyke brown, indigo, lac de vin, various kinds of gelatines.

962c. Pigmented Papers, in various colours, with subjects printed to show the various shades.

962d. Transfer Papers (*i.e.*, papers prepared with insoluble gelatine, and upon which the pictures finally rest).

962e. Sawyer's Patent Flexible Support (being paper prepared with insoluble gelatine and an aqueous solution of lac, upon which the picture is first developed previously to its transfer to the final support. *The Autotype Company.*

962f. Reversing Mirror, being a piece of plate glass polished to a perfectly true plane, and silvered by a chemical process used to produce *reversed* negatives, enabling them to be printed by the single transfer process of permanent pigment printing. *The Autotype Company.*

962g. Wave Bath, for nitrate of silver solution (being a new and convenient form for sensitizing large plates with a comparatively small quantity of solution. *The Autotype Company.*

962h. Sawyer's Callotype Process.
The Autotype Company.

Glass plates prepared with gelatine and isinglass, potassium dichromate, &c., hardened by a spirituous extract of gum resins, upon which the photograph is impressed by the action of light; after which they are placed in a type printing press, damped, and inked by lithographic rollers.

(*a.*) Plate in first stage of preparation.
(*b.*) Plate ready for exposure under negative.
(*c.*) Plate after exposure under negative.
(*d.*) Plate after being inked up in the press.
(*e.*) Plate with the same picture partly showing on the paper and partly on the plate.

988i. Four Prints from Photographs, by Paul Pretsch's mechanical process. *Robert Sabine, Regent's Park.*

VIII.—EDUCATIONAL.

963. Two Frames with 126 Photographs on Glass, for projection by the lantern, for instruction in the natural sciences.

Romain Talbot, Berlin.

964. Four simple Models, for instruction in the use of the telescope and the microscope.

J. Wilhelm Albert, Frankfort-on-Maine.

The four models for optical instruction are open instruments with lenses and shades. They show the course of the rays and illustrate in a simple manner the Galilean, astronomical, and terrestrial telescopes, and the compound microscope.

These models are largely used in German and foreign educational institutions.

965. Coloured Chalks for lectures, with a Black Board.

C. Blattner, Munich.

966. Interference Apparatus by Fresnel, executed for educational purposes by Ch. Jung, Giessen.

Physical Collection of the University of Giessen; Professor Buff.

967. Handy Educational Apparatus, for fundamental experiments on **Refraction.**

Professor Dr. J. J. Oppel, Frankfort-on-Maine.

This apparatus is only a modification of the old experiment of viewing a coin at the bottom of a basin full of water. The coin is replaced by a white line upon black ground, and the water through a movable cube of glass. The position of the eye is fixed by a dioptric plate.

968. Handy contrivance for illustrating **astronomical refraction** and its effect on measured heights of stars.

Professor Dr. J. J. Oppel, Frankfort-on-Maine.

The eye looks through a dioptric plate over a wooden globe ("earth") towards a few stars and the rising moon, which appears above or below the horizon, according as the piece of glass, which represents the refracting atmosphere, is lifted up or removed by means of a contrivance attached to it.

969. Two Colour-tables, for illustrating "colour blindness," with greenish glass (absorbing the ends of the spectrum) belonging to them. *Professor Dr. J. J. Oppel, Frankfort-on-Maine.*

Both tables, each with 10–12 colour-couples upon black ground, have references to the most frequent form of achromatopsy, the so-called *red*, respectively *green*, blindness. The one table contains colour-couples which are most generally mistaken for one another; the other such that are never mistaken. The green glass, added to the tables, enables a normal eye to get an idea of the correctness of the preceding statements.

970. Apparatus for illustrating the Colours of double refracting Bodies, in the form of a Gothic window, composed of gypsum plates systematically arranged according to the colours; with a blackened glass plate belonging to it.

Professor Dr. J. J. Oppel, Frankfort-on-Maine.

971. Some characteristic Drawings for illustrating the **Stroboscopical Principle,** with manifold movements, as,—forwards and backwards, centripetal and centrifugal, undulatory, oscillatory, and quite irregular.

Professor Dr. J. J. Oppel, Frankfort-on-Maine.

Is a collection of those principal forms of periodic movements which can be represented stroboscopically.

IX.—MISCELLANEOUS.

971a. Wheatstone's Apparatus. *Paris Observatory.*

971b. Interferential Apparatus, by Arago.

Paris Observatory.

971c. Curve for obtaining **Wave-lengths** of **Spectra;** and **Map** of the absorption spectra of bromine and iodine monochloride.

Professors Roscoe and Thorpe.

972. Mixoscope (colour-mixer), executed according to the directions of the contributor by M. Ph. Edelmann, Munich.

Prof. W. von Bezold, Royal Polytechnic School at Munich.

This apparatus permits the preparation of the true mixing colour of two colours by actual trial with the brush, and thus a correct colour table can, by its means, be made with greater facility than with Newton's disc. The achromatised calcspar prism is so to be adjusted that on looking through the apparatus only six squares should be visible. It is easy to find this position through moving the telescope and turning the prism. On bringing the two colours to be mixed under two of the square openings, these colours will be right and left of the mixed colour, which fills the middle part of the three contiguous squares. If, now, the other two apertures contain the optical true mixed colour, the two central squares will appear in the same tint.

Compare the description annexed to the apparatus.

973. Clockwork for colour discs, for lectures with discs, according to Kühne's and Becker's principles.

Rud. Jung, Heidelberg.

The clockwork, provided with a strong spring, is capable of rotating coloured discs of 28 centim. diameter with such velocity that a disc covered with the tints of the spectrum will appear white. By a simple contrivance the

one or the other of the spectrum colours can be excluded, and thus its complementary and contrast colour produced. By inserting a second axle, the movements of the clockwork can be retarded.

974. Apparatus for demonstrating the **Glory on bedewed Meadows,** consisting of glass globes filled with water.
Professor Dr. Lommel, Erlangen.

975. The same, with drops of Canada balsam become torpid.
Professor Dr. Lommel, Erlangen.

These glass globules serve to demonstrate why dew drops shone upon by the sun appear so brilliant just round the shade of the head of the observer. The explanation is that each dew drop is a lens concentrating the rays upon the ground below the drop, which latter sends them back diffused.

If the glass globules are placed upon a sheet of white paper, and the shadow of the observer's head is permitted to fall into the circle, the globules will appear very brilliant; as soon, however, as the white reflecting sheet is removed, and the globules rest on a dark dull ground, the brilliancy at once disappears.

The preceding experiment can also be well executed with solidified drops of Canada balm.

976. Four Absorption Cases, all in glass, 5 and 10 mm., two and two pieces for spirits and water.
Warmbrunn, Quilitz, and Co., Berlin.

977. Bunsen's Apparatus for Experiments in Spectrum Analysis, a battery of four Leyden jars, a stand with arrangements for producing a spark spectrum, with holder for two spectrum tubes. *Keiser and Schmidt, Berlin.*

977a. Actinometer. *Prof. Balfour Stewart.*

978. Apparatus for converting light into chemical, electric, magnetic, and mechanical motion. Length, 38 centim.; width, 38 centim.; height, 33 centim. (A drawing is sent with the instrument.) *Prof. Théodore Schwann, Liége.*

The apparatus consists of two plates of platinum placed horizontally and not in contact, which serve as electrodes to a galvanometer of Du Bois Reymond of 28,000 revolutions. The plates are enclosed in an ebony box, fitted with two wooden covers, which can be taken off separately, so that one electrode can be exposed to the light, whilst the other remains in darkness. A small square piece of blotting paper is first dipped into nitrate of silver, then dried, and dipped, without being exposed to light, into a solution of iodide of potassium. The paper thus prepared is placed, always in darkness, on the two electrodes, so that the needle of the multiplier is at zero.

The covers being in place, light, or better still, a sun ray, is admitted outside; one of the covers is then removed. At the end of a few seconds the needle begins to deviate from 40° to 60°. If the cover be replaced, the needle returns to zero, and the experiment may thus be frequently repeated.

The apparatus can also be used to determine the influence of light on chemical combinations which are not photographic, or on chemical actions in which light is supposed to play a part. The experiments are not as yet sufficiently advanced. The apparatus is not described.

978a. Apparatus for measuring the magnitude of Gas Jets at a distance. Invented by Mr. C. Wolfberger.

Geneva Association for Constructing Scientific Instruments.

This apparatus, invented by the civil engineer Wolfberger, is intended for the surveying, from the street level, of gas lamps.

Founded on the principle of the sextant, it is composed of two mirrors: the one fixed, the other movable parallel to the first along a graduated scale.

In order to measure the magnitude of the gas jet, the operator holding the instrument by its handle on a level with the visual ray, and looking through the diaphragm, sights simultaneously in a direct line the jet to be measured, above the fixed mirror, and indirectly the reproduction of the same jet by double reflection. The swivel placed below the handle is then turned, until the right edge of the jet, seen in a direct line, coincides with the left edge of the jet, seen by reflection. The magnitude of the jet, or flame, ascertained, is then shown on the metallic scale which is reckoned in millimetres.

978b. Patent Illuminating Power Meter, for showing the illuminating power of gases in the terms of the Parliamentary sperm candles and the standard quantity of five cubic feet of gas per hour by the observation of one minute. *William Sugg.*

979. Trepiscope. An optical machine made by the late Richard Roberts, of Manchester, and first shown at the meeting of the British Association at Dublin in 1835.

The Committee, Royal Museum, Peel Park, Salford.

The machine being turned by hand or by power will cause the card on the disc to revolve from 6,000 to 40,000 times a minute; on viewing the revolving disc *through the eye-hole*, the printing on the card can be read with ease and distinctness.

The time given for one view of the card does not exceed the 150,000th of a second when the disc is revolving at the highest speed.

979a. Phosphoroscope, by Becquerel.

M. J. Duboscq, Paris.

980. Radiograph.

The Committee, Royal Museum, Peel Park, Salford.

A small machine to show that the spokes may be counted whilst the wheels revolve at a very high velocity, probably the highest attainable. Invented by the late Richard Roberts, C.E., of Manchester.

981. Newtonian Disc, for rotating movement transmitted by caoutchouc bands. *Luizard, Paris.*

981a. Newton's Apparatus. *M. Lutz, Paris,*

982. Clock for producing Eclipses in groups, on Sir Wm. Thomson's plan in azimuthal condensing lights, by periodically dropping a screen over the flame.

Chance Brothers & Co., Birmingham.

983. Pair of Reflectors, for the demonstration of the laws of reflection. *Elliott Brothers.*

983a. Reflector of 22 mm. diameter, for Foucault's telescope. *M. Lutz, Paris.*

983b. Apparatus illustrating Persistency of Vision. *Sir F. Pichler.*

SECTION 8.—HEAT.

WEST GALLERY, UPPER FLOOR, ROOM Q.

I.—SOURCES OF HEAT.

984. Double-Chambered Lamp and Reservoir for heating water or air, or both. There is no blast-pipe, or communication between the chambers. *J. L. Milton.*

The heat is generated by the combustion of methylated spirit, and applied on the principle of driving a ring of flame from the holes in the top of the outer chamber against the flame issuing from the inner compartment, thus securing a great and continuous heat. The spirit in the inner chamber alone requires to be lighted. A chambered and tubed reservoir accompanies the lamp. The consumption of 1 oz. of methylated spirit in the outer, and ½ oz. in the inner chamber, will produce and maintain, for from 10 to 15 minutes, as great a heat for a vapour-bath as most persons can bear.

985. George's Patent Gas Calorigen, for warming and ventilating apartments. *John F. Farwig.*

The peculiarity of construction in this gas stove, which diffuses heat principally by convection, consists of an outlet so arranged with regard to the inlet (both being external to the apartment) that only so much air passes either way as is required to support and carry off the products of combustion.

The heat generated by combustion warms a thin coil of sheet iron in the interior of the stove, the coil being in communication at one end with the external atmosphere, and at the other with the apartment; thus a stream of fresh air, which is warmed in its passage, is drawn into, and equally diffused throughout, the apartment.

986. Bunsen Burner, improved form, with air jet to increase the temperature of the flame to any required extent without re-adjustment of height or position. *Thomas Fletcher.*

In the above, the blow-pipe flame obtained with the blast tube, when confined by the loose cap, is compact and very powerful, owing to the partial mixture of air before the blast begins to act.

987. Patent Injector Gas Furnace, with blower, for the treatment of refractory substances at very high temperatures. *Thomas Fletcher.*

This furnace will burn perfectly in the same space any available gas supply from 10 to 50 ft. per hour, or more, if required, giving temperatures in exact proportion. With ½ inch gas supply, day pressure, starting with a cold furnace, silver can be melted in three minutes, cast iron in eight minutes, and

cast steel in 25 minutes. The highest temperature obtained is 9,000° Fahrenheit. Although a foot blower is used, it must not be classed as a furnace, for the air supply required is very small. Owing to the great heating power of London gas, furnaces stated to give certain results are not verified elsewhere.

988. Low Temperature Gas Burner, to dispense with drying closets, sand and water baths, and adapted for drying, evaporating, boiling, &c. *Thomas Fletcher.*

This burner gives a range of temperature from a gentle current of warm air without visible flame to clear red heat, and is so perfectly under control that a common glass bottle may be placed on tripod, and heated to required temperature, without risk of fracture.

For very low temperatures, the ring must be lighted through the lowest opening. This gives a steady current of heated air through the gauze above. For boiling, &c., a light must be applied on the surface of the gauze, thereby providing a large body of blue flame, which can be urged by the blast-pipe until it gives a clear red heat.

989. Hot Blast Blowpipe, for temperatures up to the fusion of platinum. *Thomas Fletcher.*

The air jet in the above is coiled round the gas pipe in a spiral form, and both are heated by three Bunsen burners underneath, which are controlled by a separate tap. By this arrangement the power is double that of the ordinary blow-pipe. When the jet is turned down to a small point of flame it will readily fuse moderately thick platinum wire.

990. Gas Crucible Furnace, for temperatures up to white heat, and requiring neither blast nor attention. *Thomas Fletcher.*

991. Gas Muffle Furnace, requiring neither blast nor attention; for temperatures up to fusing point of cast iron. *Thomas Fletcher.*

992. Diagram of the Porcelain Furnace at Sèvres. Part of it being open to show the interior construction. Painted by Mr. Hubertus Sattler.

Dr. Alexander Bauer, Professor, Polytechnic Institute, Vienna.

993. Diagram of the Bottom of a Blast Furnace for Smelting Iron.

Dr. Alexander Bauer, Professor, Polytechnic Institute, Vienna.

994. Government Safety Magazine Lamp. *J. Gardner & Sons.*

Designed, by request of the Home Office, to burn in gunpowder magazines and other dangerous places in perfect safety, and to exclude the powder which is found floating in magazines and stores in the form of fine dust, allowing it to collect inside the lamp and explode, the explosion penetrating the gauze,

and carrying with it incandescent particles of powder. The supply and exit air pasages are under and over a series of screens. Air, to support combustion, enters the lamp under an inverted outer edge, and then passes through the holes made in the casing to a narrow space formed by an inner lining, so that the air must first pass up to reach the holes in the casing, then down the inner space, and finally up a narrow space between. The top part of the lamp is constructed on substantially the same principle—that is, the exit air passages are made zig-zag, two out of three parts which form the passages are hinged to the casing, and are secured by a spring lock. When these parts are unbolted they can be turned back on their hinges, and easily cleared of any soot that may have become deposited in them. The bottom and sides of the lamp are immovable, and the burner is dropped in through the top of the lamp, which is secured with a spring lock, as already mentioned. Every detail of the outer casing has been carefully considered, and there are no projecting parts where dust can settle and accumulate. The lamp has a bull's-eye in front; the side lights are glazed with glass one-eighth of an inch thick, protected by strong copper wire. The handle moves on a pivot. The burner is a three-quarter inch flat wick, and a reflector is added to increase the brilliancy. The lamp and lantern are made of copper, bright tin, or tin japanned. The highest temperature ever observed on the outside of the lantern has been 126°, the exploding temperature of gunpowder being 600°.

995. Gas Furnaces. System Perrot.
Geneva Association for Constructing Scientific Instruments.

These may be set up wherever gas is laid on; the slightest draught is sufficient; and in default of a chimney in the workroom it is enough to let out the funnel through a window pane. The shape of these furnaces varies according to their intended use. There are two principal models, the melting furnace, and the muffle furnace; the latter is advantageously used for assaying copper, gold, and silver, for roasting minerals, and for melting metals for analytical purposes.

Temperatures attaining 1,300 and 1,400 degrees can be obtained rapidly and with economy, and once obtained can be maintained unchanged during any length of time, and may be reduced at will.

996. Cowper's Regenerative Fire-brick Hot-blast Stoves. *E. A. Cowper.*

The diagrams and model of regenerative fire-brick hot-blast stoves are illustrative of the progress of science as applied to heating the air supplied as a blast under pressure to blast furnaces for smelting iron ores and iron stone. In early times the air was always used cold, but a blast heated in cast-iron pipes was introduced by Mr. J. B. Neilson in 1829, and from that time till the year 1857 the temperature of the blast was generally only about 600° Fahrenheit, but by the application of regenerative fire-brick hot-blast stoves the temperature of the blast has been raised to 1400° and 1500° Fahrenheit, and has been accompanied by a very large saving of fuel, amounting in some cases to 7 cwt. 3 qrs. 14 lbs. of coke per ton of iron made, whilst at the same time a largely increased make of iron has been produced, varying from 20 to 30 per cent. of the original make of iron. The entire wear and tear of cast-iron pipes is avoided, as the air only passes over fire-brick surfaces previously heated by the combustion of the waste gases obtained from the top of the blast furnaces. Two stoves are used alternately, one heating blast whilst the other is being heated.

997. A Gas Lamp, consisting of four Bunsen burners, and provided with an air-regulating system.

S. Hoogewerff, Dr. Phil., at Rotterdam.

This lamp, which is intended for heating tubes, was constructed by Mr. Verkerck, mechanical engineer, at Utrecht, under the directions of Dr. Hoogewerff, and belongs to the middle school at Rotterdam.

998. A Gas Lamp (Bunsen's system), intended for heating porcelain vessels of large size.

S. Hoogewerff, Dr. Phil., at Rotterdam.

It was constructed, under the directions of Dr. Hoogewerff, by Mr. Verkerck, mechanical engineer, at Utrecht, and belongs to the middle school at Rotterdam.

999. Apparatus for showing **the liberation of heat** during solidification. *Will. Haak, Neuhaus am Rennweg, Thüringen.*

II.—THERMOMETRY AND PYROMETRY.

1000. Thermometer. "The Great Pyramid temperature scale, and its standard reference point of 50° P." With a map of the world to illustrate the advantages of this standard.

Prof. Piazzi Smyth, Royal Observatory, Edinburgh.

This consists of a large table thermometer, graduated according to the indications of the Great Pyramid system of standards; firstly, by colours into fifths of the distance between freezing and boiling of water, and then each fifth into 50, or 250 for the whole distance.

A map of the world on an equal-surface projection accompanies the thermometer, and exhibits the mean temperature of the whole earth's surface according to the Great Pyramid scale; illustrating also the territorial and international advantages to all civilised nations of adopting the mean temperature standard of the Great Pyramid, viz., 50° Pyr. or 68° Fahr., as the temperature reference standard for all human purposes, scientific, social, and commercial.

1001. Legible Spirit Thermometers, with line at above and below the proper temperature of a room, so that the degree can be read off at a long distance, at the opposite side of a large room, or at the ceiling, for experiments in ventilation.

Peter Hinckes Bird, F.R.C.S. Lond.

1002. Apparatus for determining the **Boiling Point of a small quantity of Fluid.**

The Secondary Government School, Assen (Netherlands).

In this simple apparatus, constructed after the design of Dr. A. Van Hasselt, (teacher at school for middle-class education at Assen), the little tube is filled for the greater part with mercury; the remaining space with the fluid. The tube is then turned upside down into a small beaker-jar, which is also filled with mercury; part of this must be removed until the quantity left rises about

one or two centimetres above the bottom of the jar. When the apparatus has been placed in the large beaker-jar, water or oil is poured into the latter, so that the tube is quite immersed. The jar is then heated, agitating the fluid meanwhile with a moving apparatus.

The millimetre scale serves to determine the height of the fluid in the great jar, together with the difference between the position of the mercury in the little tube and that on the outside of it. With respect to determining this difference, the pressure of the fluid in the great beaker-jar and the barometric height must be taken into consideration. Thus, when the pressure of the fluid in the great beaker-jar is equal to half a centimetre of mercury, and the barometric height $76\frac{1}{2}$ centimetres, the thermometer must be observed, when the mercury in the tube is 1 centimetre higher than that at the outside of it.

To know whether a fluid is homogeneous, two experiments must be made, one with a fluid which is partially evaporated. In both cases the results must be the same.

When the vapour of the fluid in the tube has the pressure of one atmosphere the boiling point of the fluid must be observed.

1003. Photographs of Old Thermometers; a small alcohol thermometer, with Florentine scale, and four larger ones by Michelo du Crest (1754).

Professor Hagenbach-Bischoff, Director, The Physical Institute in the Bernoullianum, Basle.

In these alcohol thermometers zero indicates the temperature of the cellar under the Observatory of Paris, and 100° the boiling point of water.

1004. Trough for comparing Thermometers, provided with in- and out-flow tubes for water, and stirring apparatus.

Dr. J. W. Gunning, Professor of Chemistry at the "Athenæum illustre," Amsterdam.

The thermometers are placed in a loose frame, in which they may be transported from one trough into another containing water of another temperature. Two loose sheets of glass, placed on either side of the frame, prevent the inner portion of the water from cooling.

1005. Dial Thermometer, designed by L. R. Brülme, Leyden.

Dr. D. de Loos, Director of the Secondary Town School, Leyden.

This thermometer is intended to admit of a large number of students seeing, from a distance, the change in the volume of the mercury as the temperature varies.

In the mercury is a small glass tube, balanced by another similar tube, both being joined together by a thread, which is suspended over a small copper box, at the extremity of which is a needle moving over a screen (or dial).

When the mercury expands, the first glass tube rises, and the needle moves. In the other case the tube descends.

1006. Mercurial Dial Thermometer, adapted for class experiments on specific and latent heat.

Prof. W. F. Barrett, Dublin.

The expansion of the mercury in the bulb of the thermometer lifts a small iron piston which communicates its motion to the index hand. Small varia-

tions of temperature are thus readily seen by a large class, *e.g.*, the expansion of the glass of the bulb causing a momentary retreat of the index hand, is seen to be the first effect produced by heat on the bulb. By making the scale on glass the dial can be projected on a screen and determination of specific and latent heat made before a large class; electric contact can also be made by the hands, and thus a self-registering thermometer constructed. The instrument was made by Mr. Yeates, of Dublin.

1011. Various Thermometers, of different kinds, in metal, ivory, porcelain, glass, and wood. *Elliott Brothers.*

1012. Standard Thermometer. *Elliott Brothers.*

1013. Insolation Thermometer, for determining the intensity of the rays of the sun (maximum thermometer), with holder. *Ch. F. Geissler & Son, Berlin.*

1014. Eight Normal Thermometers, executed by Greiner and Geissler, Joint Stock Company, Berlin.
Imperial Admiralty Hydrographical Bureau at Berlin, and Deutsche Seewarte in Hamburg.

These thermometers are employed in the stations of the Naval Observatory and in the Imperial Navy.

1015a. Thermometer, with corrected Freezing Point.
W. Gloukhoff, St. Petersburg (Russia).

This thermometer is constructed on a principle much used in Germany. To it is added only a contrivance to render the scale more steady, and to correct the error of *freezing point,* by raising or lowering of the scale. By unscrewing the upper metallic cap of the thermometer, this contrivance becomes visible.

1016. Reaumur's Scale. *Dring and Fage.*

Formerly much used in Germany and Russia, now mostly in Norway and Sweden, and some parts of Denmark. The zero of this scale is at the point of melting ice. The interval between this and boiling point is divided into 80 degrees.

1017. De Lisle's Scale. *Dring and Fage.*

This scale is seldom used; zero is fixed at boiling point; the interval between this and freezing is divided into 150 degrees.

1018. Six's Thermometer on a porcelain scale (named after its inventor, Mr. Six of Canterbury) for registering extremes of temperature. *Dring and Fage.*

The indices are little pieces of steel coated with glass which are enabled to retain their position in the tube by means of a hair fastened round them, and by this means the highest or lowest temperature is recorded.

1018a. Six's Thermometer with a very flat bulb which renders it as sensitive as an ordinary mercurial thermometer.
S. G. Denton.

1018b. Six's Thermometer with mercurial wet bulb thermometer attached, thereby combining four instruments in one, namely, maximum, minimum, hygrometer, and present temperature. *S. G. Denton.*

1019. Long Brass-Cased Thermometer. Showing the difference in length of the mercurial column after being pointed and divided with the whole length of the tube immersed in water at the various temperatures between 32° and 212°; the same with the bulb only in the water. *Dring and Fage.*

1020. Very delicate Spiral Bulb Thermometer. Extremely sensitive, capable of indicating small variations of temperature. *Dring and Fage.*

1022. Standard Thermometer, calibrated throughout. *Dring and Fage.*

A standard thermometer divided on the tube, used for purposes where great accuracy is required. The tubes used for these thermometers are selected with great care, particular attention being paid to the uniformity of the bore. The method of ascertaining this is usually performed as follows:—A portion of mercury is introduced into the tube, and the length it occupies is noted; it is then carried a little further on, and its length compared with the former length. So on all down the tube; if the length has decreased from the first measurement, it shows that the bore of the tube has increased, and vice versâ. The process is known as calibration.

1023. Four Thermometers. Showing the different scales principally in use. Fahrenheit, Celsius or Centigrade, Reaumur, and De Lisle. *Dring and Fage.*

Fahrenheit's scale is used principally in Great Britain, its Colonies, and the United States. The zero of this scale is obtained from a mixture of salt and snow; thirty-two degrees is the point at which ice begins to melt, and 212, or boiling point, from boiling water, when the barometer stands at 29·905. One advantage of this scale is that temperatures may often be expressed in whole degrees, whereas in other scales fractions of degrees are frequently necessary.

1024. Celsius or Centigrade Scale. Generally used on the continent. *Dring and Fage.*

The zero of this scale is that point at which ice begins to melt, and 100 the point at which water boils when the barometer stands at 760mm. Celsius is the name of the inventor of this scale; it is called Centigrade from its being divided centesimally.

1025. Becquerel's Thermo-Electric Thermometer. *Conservatoire des Arts et Métiers, Paris.*

1025a. M. Becquerel's Thermo-Electric Pyrometer. *Conservatoire des Arts et Métiers.*

1026. Hodgkinson's Actinometer. Actinometer by the Rev. G. C. Hodgkinson, described in the Proceedings of the Royal Society, vol. XX., p. 328. *Kew Committee of the Royal Society, Kew Observatory.*

It is a large thermometer, filled with alcohol coloured blue, and having a bore much contracted for a great part of its length, in order that the scale

may be very open at its top; it opens out into a large chamber, which receives the superfluous fluid at the time of observation.

A tin case, capped at both ends, prevents the access of extraneous rays to the bulb of the instrument at the time of observation.

1027. Original Spirit Thermometer, of the Florentine Accademia del Cimento (17th century).

The Royal Institution of Great Britain.

Presented to the Royal Institution by Sir Henry Holland, Bart., F.R.S.

1028. Drawings, various, partly new, of constructions of Differential Atmospheric Thermometers.

Dr. Leopold Pfaundler, Professor of Physics at Innsbruck.

This plate presents a general view of all possible forms of construction, which partly appear as modifications of Berthelot's atmospheric thermometers, partly are based on independent principles.

For further details, see Transactions of the Imperial Academy of Sciences at Vienna, Vol. LXXII., 1875.

1029. Melloni's Thermo-Electric Apparatus.

M. Ruhmkorff.

1029a. Line Pile for Spectrum and Galvanometer.

M. Ruhmkorff.

1030. Galvanometer for Thermo-Electric Currents.

Luizard, Paris.

1031. Pyrometers and Thermometers.

Conservatoire des Arts et Métiers, Paris.

1032. Collection of Thermometers.

Dr. H. Geissler, Bonn.

1033. Thermo-Electric Alarum, for giving notice when a given temperature is reached. *Dr. Letts.*

The apparatus consists of an open thermometer with large bulb and wide tube. A platinum wire is sealed into the bulb, and another wire passes down the tube. The latter can be so adjusted that at a given temperature its end is touched by the mercury in the tube. The two wires being connected with an electric bell and battery, as soon as the mercury touches the wire, contact is made and the bell rings.

The apparatus was used in experiments with the glass digester, and served to give notice at some distance from the room in which the latter was being heated when the desired temperature had been reached, thus rendering an actual observation of the temperature unnecessary, and so preventing all danger in case of an explosion.

1034. Normal Thermometer, divided in tenths of a degree from 0° to 105° C.

Will. Haak, Neuhaus am Rennweg, Thüringen.

1035. Normal Thermometer, in a narrow glass cylinder with a small mercury bulb; divided in tenths of a degree from 0° to 105° C. *Will. Haak, Neuhaus am Rennweg, Thüringen.*

1036. Normal Thermometer, divided in tenths from $-35°$ to $+50°$ C. *Will. Haak, Neuhaus am Rennweg, Thüringen.*

1037. Two Thermometers, on the plan of Virchow, for physiological investigation.
Will. Haak, Neuhaus am Rennweg, Thüringen.

1038. Two Thermometers, for chemical work, from $-10°$ to $+360°$. *Will. Haak, Neuhaus am Rennweg, Thüringen.*

1039. Two Thermometers, from 100° to 360°.
Will. Haak, Neuhaus am Rennweg, Thüringen.

1040. Two Thermometers, from 0° to 150°.
Will. Haak, Neuhaus am Rennweg, Thüringen.

1041. Two Thermometers, with divisions etched on the tube. *Will. Haak, Neuhaus am Rennweg, Thüringen.*

1042. Two Thermometers, for medical purposes, on the plan of Traube, divided in tenths from $+25$ to $+45°$ C.
Will. Haak, Neuhaus am Rennweg, Thüringen.

1045. Various Pressure Thermometers, on the plan of Mitscherlich. Consult the adjoined pamphlet.
Prof. Mitscherlich, Münden.

1046. Suture Thermometer, on the plan of W. Beetz, constructed by Sauerwald, of Berlin. Consult the adjoining description and scheme. *Prof. Beetz, Münich.*

1047. Model of an **apparatus for measuring temperatures by means of thermo-batteries.**
Dr. T. Pernet, Breslau.

The apparatus permits the quick and reliable determination of the temperature of the several soldered places, as well as the differences of temperature of any two soldered places.

In the first case the resistances of the single conductors (except the resistances of the two soldered places, which are exposed to constant temperatures, and show always the same resistance) may be different. In the other case the resistances of all soldered places must be capable to be made equal.

1048. Diagrams, illustrating the application of the **apparatus for the measurement of the temperature of the earth** and of metal tools. *Dr. T. Pernet, Breslau.*

1049. Normal Thermometer, divided in tenths of a degree from $-5°$ to $+105°$ C. *Ch. F. Geissler and Son, Berlin.*

1050. Chemical Thermometer from $-10°$ to $+360°$ C.
Ch. F. Geissler and Son, Berlin.

1050a. Thermometer for Cooking, range to 600° F.
Harvey, Reynolds, and Co.

See Mrs. Buckton's book "Health in the House," page 153.

1051. Apparatus for determining the **temperature of fusion.** (Compare the adjoined description.) *Prof. Dr. Himly, Kiel.*

1052. Air Thermometer on the plan of Jolly. Compare Poggendorff's Annalen, Jubelband, 1873.
University of Munich (*Prof. v. Jolly*).

1052a. Original Air Thermometer, by Mr. Regnault.
College of France.

1053. Thermopile on the plan of Melloni of 64 bismuth antimony elements. *Wesselhöft, Halle.*

1054. Thermometer Stick for measuring temperatures at some depth. *Ludwig Meyer, Berlin.*

The instrument, adapted for depths down to 3 feet, is chiefly distinguished by the strength of its construction.

The bulb is in the nickel clamp, which latter stands by means of mercury in thermal connexion with the bulb. This mercury serves also as buffer to the thermometer bulb.

The horn clamp is replaceable by an iron screw, which facilitates the introduction of the thermometer into the ground.

Care is taken that only the clamp be thermo-conducting, not the whole tube.

1055. Milligrade Thermometer. The milligrade scale is one in which the interval of temperature between the freezing and boiling points of mercury is divided into one thousand degrees.

According to Dulong and Petit, mercury freezes at $-39 \cdot 44°$ C., and boils at $+360°$ C. For convenience, assuming that the freezing point is $-40°$ C., the interval is therefore 400 degrees C., thus it follows that $2\frac{1}{2}$ degrees milligrade are equal to 1 degree centigrade. Upon this scale the following results are obtained. Water freezes at 100° M. and boils at 350° M., the interval 250° being just one-fourth of the interval between the freezing and boiling points of mercury. Many other substances also show a curious relation in the interval between their freezing and boiling points to that of mercury, facts which are not obvious upon other thermometric scales.

The practical advantages of this system of graduation consist in the comparative smallness of the degrees, thus avoiding in many cases the necessity of the use of fractions to express the boiling point of substances; also that the zero point being so low the scale is a continuous one, all numbers under 100° M. representing temperatures below freezing water, but avoiding the necessity of the use of the minus sign, and at higher temperatures as 1,000° is approached, giving a clear idea that the heat is arriving at the extreme limit of thermometric registration.

In practically graduating this thermometer reference is not made to the freezing or boiling points of mercury, but the freezing point of water is marked as 100°, and the boiling point as 350°, and the scale carried upwards or downwards as required.

The conversion of centigrade degrees into milligrade degrees, or *vice versâ*, is extremely simple. A centigrade degree multiplied by $2\frac{1}{2}$, and 100

added, gives the milligrade degree, thus 40° C. multiplied by $2\frac{1}{2}$ is 100, and 100 added gives 200, the degree on the milligrade scale. The correspondence between the Fahrenheit and the milligrade graduation is not so simple, as the interval on the Fahrenheit scale between the freezing and boiling points of water being 180° F., higher numbers are required to be used in the calculation. The following are the lowest common numbers for the scales :— 25° milligrade, equal to 10° cent. and equal to 18° Fahr.

Thus it follows that the following rules can be applied to calculate one scale with the others—

To convert centigrade into milligrade degrees	-	$n \times 5 \div 2 + 100$.
To convert milligrade into centigrade degrees	-	$n - 100 \times 2 \div 5$.
To convert Fahrenheit into milligrade degrees	-	$n + 40 \times 25 \div 18$.
To convert milligrade into Fahrenheit degrees	-	$n \times 18 \div 25 - 40$.

John Williams, F.C.S.

1055a. Thermometer, with 19 differently graduated scales, traced on a silvered metal plate ; the midst is taken in by the thermometer-tube and bulb. This instrument was made in 1754.

Professor Buys-Ballott, Utrecht.

1055b. Four Registering Thermometers.

E. Cetti and Co.

1055c. One Siemgan's Pyrometer. *E. Cetti and Co.*

1055d. Metallic Thermometer, indicator of two temperatures. *Francis Pizzorno, of Bologna (Italy).*

The movements of the index are in this instrument produced by the dilatation of two zinc blades which in the figure are seen edgewise. Along the graduated arc can be fixed two sliding pieces ; if the index touches one of them, it closes an electric circuit and a ring bell placed in action. Two small pearls carried by a thread stretched between the extremities of the graduated arc, and which are displaced by the index in its movements, serve to indicate the maximum and minimum temperature.

1055e. Five Thermometers, various. *E. Cetti and Co.*

1067. Wedgwood's Pyrometer, consisting of pieces of clay, contracting according to the heat to which they are exposed. These are afterwards slid along the gradually diminishing and graduated groove in the brass plate, and so indicate the degree of heat to which they have been exposed. *Robert Garner, F.R.C.S.*

1068. Pyrometer, of iron and copper, for lecture illustration.

Yeates & Sons.

The above consists of a compound bar of iron and copper, bent into the form of U, one arm of which is firmly attached to the stand ; the other arm is free, and carries a long index. If the compound U be immersed in a beaker of boiling water, the index will move over several degrees of the scale.

1069. Reflecting Pyrometer, for showing the difference of expansion of different metals. *Yeates & Sons.*

1070. Wedgwood's Pyrometer, invented in 1782.

Edinburgh Museum of Science and Art.

Dry clay when exposed to high temperatures contracts uniformly, and Wedgwood believed that by the amount of contraction the temperature which produced it could be measured. The instrument, however, is not reliable. This specimen was made by Josiah Wedgwood, and presented to the Edinburgh Museum by his grandson Mr. Godfrey Wedgwood.

1071. Copper Pyrometer, for determining the temperature of blasts. *E. A. Cowper.*

The temperature of the blast is readily ascertained by heating a small piece of copper in it, and then dropping the copper into a pint of water in a copper vessel surrounded by a non-conductor, and where a thermometer shows one degree for every fifty degrees the copper had been heated. The thermometer is provided with two scales, one fixed, showing the temperature of the water, the other sliding, showing the temperature of the blast.

1074. Pyrometer. *O. Schütte, Cologne.*

The pyrometer for determining the temperature of the heated blast-current deserves particular attention on the part of proprietors, overseers, &c. of foundries, on account of the simplicity of its construction, which is proof against deranging influences, although constantly exposed to a destructive element, viz., the glowing hot current, the more especially as no pyrometer has been made as yet with which temperatures up to 600 degrees Celsius and more can be continuously determined.

By the application of this pyrometer it will be possible to control at any time the apparatus and the stokers, and in cases where Siemens' or other similar apparatus are employed, to determine the exact time when the same must be reversed. The pyrometer, likewise, indicates any disturbing influences occurring in the flues, variations in the fuel, in the atmosphere, &c., and thus offers the best guarantee that the heating of the apparatus is not forced to such an extremity as to cause the destruction of the pipes, stop-valve, &c.

1074a. Water Pyrometer. *C. W. Siemens.*

The pyrometer consists of a copper vessel, capable of holding rather more than a pint of water, and well protected against radiation by having its sides and bottom composed of a double casing, the inner compartment of which is filled with felt. A good mercury thermometer is fixed in it, having, in addition to the ordinary scale, a small sliding scale, graduated and figured with 50 degrees to 1 degree of the thermometer scale; there are also some cylindrical pieces of copper provided with the pyrometer, each accurately adjusted in size, so that its total capacity for absorbing heat shall be 1–50th that of a pint of water.

In using the pyrometer, a pint (0·568 litre, or 34·66 cubic inches) of water is measured into the copper vessel, and the sliding pyrometer scale is set with its zero at the temperature of the water as indicated by the mercury thermometer; a copper cylinder is then put into the furnace or hot blast current the temperature of which it is wished to ascertain, and is allowed to become heated for a time varying from 2 to 10 minutes, according to the intensity of the heat to be measured.

It is then to be withdrawn and quickly dropped into the water in the copper vessel, where it raises the temperature of the water in the proportion of 1 degree for each 50 degrees of the temperature of the copper. The rise of the temperature may then be read off at once on the pyrometer scale, and, if to this is added the temperature of the water as indicated on the mercury thermometer before the experiment, the exact temperature required is obtained.

For very high temperatures platinum cylinders may be employed instead of copper.

1074b. Electrical Pyrometer. *C. W. Siemens.*

The electrical resistance of metal conductors depends upon their dimensions, material, and temperature; an increase of the latter causing a corresponding increase of resistance. The law of this increase is known.

Thus, the resistance of a conductor being ascertained at 0 degree centigrade, it can be calculated for any temperature, and *vice versâ;* if the resistance can be found by measurement, the temperature can be calculated. This is the principle upon which Siemens' electrical pyrometer is based.

A platinum coil of a known resistance at 0 degree centigrade is coiled on a cylinder of fire-clay, protected by a platinum shield, which is placed in an iron or platinum tube, and then exposed to the temperature to be determined. Leading wires are arranged to connect this coil with an instrument suitable for measuring its resistance, and from this resistance the temperature can be calculated.

The instrument supplied for this purpose is a differential voltameter.

The differential voltameter consists of two separate glass tubes, in each of which a mixture of sulphuric acid and water is decomposed by an electrical current passing between two platinum electrodes. The gas which is generated is collected in the long cylindrical and carefully-calibrated top of the tube, and its quantity is read off by means of a graduated scale fixed behind the tubes.

Movable reservoirs are provided communicating with the tubes to regulate the level of the liquid.

The current of the battery is divided (by passing a commutator) into two circuits, one of which consists of standard resistance in the instrument and the platinum electrodes in one tube; the other, of the resistance to be measured and the electrodes in the other tube. The quantities of gas developed in the two tubes are in inverse proportion to the resistances of their respective circuits, therefore one of the resistances, viz., that in the instrument, being known, the other can be calculated.

Directions for use :—Fill the battery glasses with pure water, or, in case of the power of the battery decreasing, with a solution of sal-ammoniac in water. Connect the poles to B and B′ on the commutator. Expose the small end of the pyrometer-tube, as far as the cone, to the heat to be measured, and connect the terminals x, x', c to the ends of the leading cable bearing corresponding letters. Connect the other end of the leading cable to the terminals x, x', c on the voltameter.

The differential voltameter is to be filled with the diluted sulphuric acid through the reservoirs, the india-rubber cushions being lifted from the top of the tubes. The commutator is to be turned so that the contact springs on both sides rest on the ebonite. The liquid in both tubes is to be regulated to the same level (0 degree of scale), and the india-rubber cushions to be let down again. Give the commutator a quarter of a turn, and the development of gas will commence almost immediately. Turn the commutator half round every ten seconds to reverse the current. Keep the current passing until the liquid has fallen in the tubes to at least 50 degrees of the scale, then put the commutator n its first position, so that the contact springs rest on the ebonite; read off the level of the liquids on the scale marked V, and the scale marked $\dot{V}$; find these numbers in the table under V and $\dot{V}$, and the intersecting point of the lines starting from these figures gives the temperature.

For a new experiment adjust the levels as before.

1075. Apparatus for demonstrating the **Expansion of Solids by Heat.** *A. Steger, Kiel.*

1075a. 'sGravesande's Ball and Ring Pyrometer, for showing expansion. *Harvey, Reynolds, and Co.*

1076. A Musschenbroek's Pyrometer from the first half of last century, with five different metal bars, and an autograph. Property of His Highness Prince Pless, Schloss Fürstenberg.
Committee of Breslau.

The apparatus has been constructed after the description and drawing given on p. 12 and Table XXX. of Musschenbroek's "Tentamina Experimen-" torum Naturalium Captorum in Academia del Cimento, Lugduni, 1731 " Pars. II." The orthography of the French, on an annexed slip of paper, is that of the beginning of the last century. The instrument, which is in capital condition, may therefore be considered as one of the oldest of its kind.

1078. Early Pyrometer (by Funiey).
Museum of Physical Apparatus, King's College.

1079. Daniell's Pyrometer, employed in researches by Professor Daniell.
Museum of Physical Apparatus, King's College.

1077. Bailey's Patent Civil Engineer's Pyrometer, for ascertaining the temperature of flues, &c., with sheath and box-wood handle to enable managers of works and others to carry it about with them for use when necessary. *W. H. Bailey & Co.*

1080. Bailey's Patent Flue Pyrometer, for testing [the temperature of boiler flues, hot-air chambers, stoves, galvanisers, &c. *W. H. Bailey & Co.*

1080a. Hobson's Patent Hot Blast Pyrometer.
Joseph Casartelli, Manchester.

In this instrument the aim is to tone down the temperature of the blast by an admixture of a constant proportion of cold atmospheric air, so that the highest temperature likely to have to be recorded is brought within the range of a good mercurial thermometer. The hot blast is introduced in the form of a jet, which by suitable arrangement is made to induce a stream of atmospheric air; the mixed stream then passes on, and impinges on the bulb of the thermometer. The scale has been laid down by experiment, and the instrument gives the same reading as Siemens' copper ball pyrometer. It is found that pressure does not affect the result; and, as all the instruments are made exactly alike, the same result is invariably obtained. By the use of this instrument much time is saved, and the result is more reliable than with any other instrument in use.

1080b. Casartelli's Improved Pyrometer, for ascertaining the temperature of flues, stoves, &c.
Joseph Casartelli, Manchester.

This instrument consists of two different metals of different ratios of expansion, and any permanent set which may take place in the metals is compensated by the fact that the set will take place in opposite directions. The scale is laid down by experiment. It is so constructed that it is only necessary to expose one half of the stem to the action of the heat.

1081. Bailey's Patent Baker's Pyrometer, "Baker's Guide," for ascertaining the temperature of bakers' ovens, and enabling them to prevent the possibility of the bread becoming burnt, by keeping the oven at one uniform temperature.

W. H. Bailey & Co.

1082. Wood and Bailey's Patent Blast Furnace Pyrometer, for ascertaining the temperature of hot blasts.

W. H. Bailey & Co.

1082a. Photograph of M. Guyeau's Apparatus for determining the **Coefficients** of **Dilatation.**

M. Laurent, Paris.

1082b. Microgoniometer. An instrument for measuring the expansion of metals by heat. *Prof. Dr. F. Pfaff.*

III.—CALORIMETRY.

1057. Apparatus employed by Dr. Andrews in his experiments on the amount of heat disengaged in the combination of hydrogen and other combustible gases with oxygen. *Dr. Andrews, F.R.S.*

The gases contained in a cylindrical vessel of thin copper are exploded by the ignition of a fine platinum wire, and the heat is measured by the rise of temperature of the water in a calorimeter, capable of being rotated gently round its horizontal axis.

1058. Apparatus for determining the amount of heat produced in the combination of liquids and solids with oxygen.

Dr. Andrews, F.R.S.

1060. Thermometric Tube for determining the calorific capacities of different liquids. *Elie Wartmann, Geneva.*

A thermometric tube, being part of the contributor's apparatus for the determination of calorific capacities in liquids. A full description of the method is printed in the number for May 1870 of the "Archives des Sciences physiques et naturelles." An electric chronoscope, such as Sir Charles Wheatstone's, expresses in thousandth parts of a second the time necessary for the cooling between two constant temperatures of the same body (the thermometric tube) when immersed in equal volumes of different liquids, at the same initial degree of heat.

1061. Apparatus made by De la Rive and Marcet for measuring the specific heat of Gases. A small copper calorimeter, containing a very thin serpentine gold pipe.

Lucien de la Rive, Geneva.

1063. Drawing of an Apparatus for determining the calorific capacity of liquid substances.

Dr. Leopold Pfaundler, Professor of Physics at Innsbruck.

In a box protected against draught there are placed two calorimeters—one filled with water, the other with the liquid to be tested. An electric current is passed through the two spiral wires, both of equal power of resistance, which are inserted in the fluids.

Two paddles stir, and two thermometers measure, the temperature of the liquids.

The respective capacities of heat are calculated from the proportion of the increment of heat.

1063a. Original Apparatus of **M. Regnault** for ascertaining **Specific Heat** by observing **Refrigeration.**
College of France, Paris.

1064. The original Lavoisier Calorimeter. Fabre and Silbermann's original calorimeter for measuring the heat disengaged in combustion. *Conservatoire des Arts et Métiers, Paris.*

1064a. Original Vessel, by **Dulong,** for measuring **Specific Heat** by **Refrigeration.** *Polytechnic School, Paris.*

1064b. Original Apparatus, by **M. Regnault,** for ascertaining the **latent Heat** of **Steam** at different pressures.
College of France, Paris.

1065a. A Calorimeter. *M. Laurent, Paris.*

IV.—RADIATION.

1056. Hargreaves's Thermo-radiometer, for measuring losses of heat by radiation from walls of furnaces, sides of steam boilers, &c. *James Hargreaves.*

The silver-plated copper vessel is filled with water and enclosed in the case, the blackened face then being exposed for a given time (say five minutes) to the radiating surface, while a thermometer inserted in the neck of the vessel shows the elevation of temperature due to radiation. The heat is calculated as follows, either in calorics or British thermal units. $\frac{WS\,(T-t)}{a\,m} = x.$ Where WS = weight and average specific heat of vessel and its contents; t, temperature of the same before exposure; T, temperature of the same after exposure; a, area of blackened face of vessel; and m, time of exposure, whence may be calculated the amount of fuel necessary to replace the heat lost by radiation.

1059. Diacalorimeter. To measure the resistance which liquids offer to the passage of heat. *Frederick Guthrie, F.R.S.*

Two conical platinum vessels, having their bases accurately plane, are supported so that their bases are parallel, horizontal, and nearly touching. The lower cone is fixed, and, being provided with an air-tight fitting vertical tube in which water stands at a known height, serves as an air thermometer and calorimeter. The upper cone can be adjusted by a micrometer screw at any

distance from the lower one. Through the upper cone a current of warm water or steam is passed. Between the bases of the cones is introduced the liquid whose thermal resistance is to be measured.

1062. Apparatus used in researches on the **Absorption** of **Radiant Heat** by gases and vapours.

Professor Tyndall, F.R.S.

Phil. Trans., 1861.

1065. A pair of concave Reflectors of Prima German silver, 500 mm. in diameter, on brass stands, with supports for carbon and tinder, for experiments on radiant heat.

Warmbrunn, Quilitz, and Co., Berlin.

1066. Melloni's Apparatus for investigating the laws of radiant heat. *H. Lloyd, Trinity College, Dublin.*

1072. Pouillet's Actinometer, for sidereal radiation.

Conservatoire des Arts et Métiers, Paris.

1072a. Actinometer, for measuring the intensity of Solar Radiation. *I. Louis Soret, Geneva.*

It is composed of a tube, of the diameter of about 35 millimetres, closed at one end, and blackened inside. The end, which can be opened by removing the stopper, is furnished with a diaphragm. The central tube is encircled with a concentric brass wrapper, which has to be filled up with pounded ice, or with snow. The apparatus is upheld by a horizontal axle upon a wooden support. This axle is formed of a tube which, on one side, lets out the rod of the thermometer (lacquered and blackened), and on the other may be adjusted to an air-exhausting pump. The apparatus is directed towards the sun ; the orientation is obtained by means of the exterior appendiculæ.

See Recherches sur l'intensité calorifique de la radiation solaire.—Comptes Rendus de l'Association Française pour l'Avancement des Sciences," 1st Session, Bordeaux, p. 282.

1072b. Actinometer.

M. Desains, Member of the Institute, Paris.

1073. Pouillet's Pyrheliometer, for observations on solar heat. *Conservatoire des Arts et Métiers, Paris.*

V.—ABSORPTION.

1084. Ice-making Machine ; system of Raoul Pictet, & Co.

Raoul Pictet, & Co., Geneva. Geneva Association for constructing Scientific Instruments.

This machine manufactures ice by means of anhydrous sulphurous acid. This substance has the following advantages :—

1. It is without action upon metals and fatty substances.
2. It gives but slight pressures, never exceeding 4 atmospheres in a temperature of 30° centigrade.

3. It is free from all danger of ignition or explosion.
4. It is the least expensive volatile liquid.

This machine turns out 12 kilogrammes of ice per kilogramme of coal con sumed.

1085. Apparatus for Freezing Water, constructed by Mr. Bieberich. Compare the adjoined instruction for use.
University of Munich (Prof. v. Jolly).

1086. Small Ammonia Ice Machine.
Vaast and Littmann, Halle.

VI.—CONDUCTION.

1087. Model of Circular red hot Copper Railway, for causing a metal ball to rotate by means of unequal expansion by heat. *George Gore, F.R.S.*

Model in wood of circular railway, which when formed of copper heated to redness, and a thin cold ball of German-silver placed upon it, the ball rotates by the influence of unequal expansion produced by the heat. (*See* Philosophical Magazine, August 1859).

1088. Forbes' Iron Bar for **Thermal Conductivity,** with its crucible. *Professor Tait, Edinburgh.*

1088a. Apparatus by **Peter von Musschenbroek,** a Dutch mathematician (born 1692, died 1761), to determine the relative values of the **Coefficients** of the **Expansion** of **Solid Bodies.** *Professor Dr. P. J. Rijke, Leyden.*

1089. German Silver Bar, of same size, cast for same purpose. *Professor Tait, Edinburgh.*

1090. M. Fizeau's Apparatus for measuring the **Coefficient** of **Dilatation.**
Conservatoire des Arts et Métiers, Paris.

1090a. Three Original Bars, by **Depretz**, on which were made the studies of the **Laws** of **Conductibility.**
The Faculty of Sciences, Paris.

1090b. Original Apparatus of **Regnault** for the **Dilatation of Gases.** *College of France, Paris.*

1091. Depretz's Apparatus for showing the **Conduction of Heat** in metals with 9 thermometers.
Warmbrunn, Quilitz, and Co., Berlin.

1092. Ingenhous' Apparatus for demonstrating the **Conduction of Heat,** with nine rods of different metals.

Warmbrunn, Quilitz, and Co., Berlin.

1093. Apparatus intended to produce the **Curves** of **Thermic Conductibility** on the surface of bodies.

On the glass support are placed plates coated with grease, which may be coloured. The current of a battery is made to pass through the small platinum ball, which is at the end of wires of the same metal, and which are put into contact with the plate.

1093b. Four Boxes, containing plates subjected to the action of apparatus No. 1, and showing the isothermic curves produced by the fusion of the grease upon—

A. Bluish schist, from the valley of Sulvan, near Vernagaz.
B. Coal schist, from neighbourhood of Motivon, near the Col de Voza.
C. Another schist from the Col de Voza.
D. Septypite from Tholy (Vosges).
E. Clayey schist.
F. Hyaline quartz, with faces cut parallel with the axis.
G. Trooshte, silicate of zinc, with faces cut parallel with the axis.
H. Gneiss, fine grained, from the Val Anzasca, Monte Rosa.

M. Jannetaz, Paris.

VII.—POLARIZATION.

1095. Forbes' Mica Plates for the polarisation of heat by refraction. *University of Edinburgh.*

The mica is split into numerous thin films by careful application of heat, and fixed in the wooden tubes at the proper polarising angle.

VIII.—MISCELLANEOUS.

1096. Thermo-electric Diagram for teaching purposes. (Trans. Roy. Soc. Edin., 1872–3.) *Professor Tait, Edinburgh.*

1097. Apparatus employed by **Professors Stewart** and **Tait** for producing rapid **Rotation** in a **Vacuum.**

Professor Stewart, Manchester.

The driving shaft is of iron, and passes into the receiver through an iron tube containing mercury, which acts as a barometer.

This instrument was constructed and in part devised by R. Beckley, of the Kew Observatory, or an experiment conducted by B. Stewart and P. G. Tait.

The mechanical principle of its construction is as follows :—The receiver in which the rotation takes place is in fact the extended vacuum of a barometer. Through the mercury of this barometer a shaft communicates a slow motion to some machinery in the receiver. The velocity of this motion is there greatly increased by means of a suitable train of wheels, until at length a vertical disc is made to rotate with great rapidity on a horizontal axis. If this disc be made to rotate in an ordinary obtainable vacuum it will become heated, and the question is to determine whether this heating of the disc is entirely due to the friction of the residual air, or to something else.

Two wires, covered with gutta percha, carried through the bed-plate of the apparatus, convey into the receiver a thermo-pile arrangement, by means of which the temperature of the disc may be measured. This thermo-pile may either measure the increased temperature of the disc after rotation by radiation—in which case it is fitted with a reflecting cone ; or it may be made to tap the surface of the disc after rotation—in which case there is an arrangement working through a barometric tube, by means of which the pile may be brought up to the disc in vacuo after rotation. Finally, there is an arrangement, working also through a barometric tube, by means of which a vessel containing some peculiar chemical substance may be uncovered in vacuo at will. The object of this is to reduce the pressure of the vacuum by chemical means. For instance, if we have a carbonic acid vacuum made as low as it can be made by ordinary means, a vessel containing moist potash would be uncovered, and a great part of the residual gas absorbed. The experimenters by this means have obtained a vacuum as low as 0·025 in. The conclusion from these experiments appears to be, that there is a certain heating of the disc which does not depend on the residual air.

1097a. Diagram representing the **Apparatus** of **M. Regnault,** by M. d'Obelliane. *Polytechnic School, Paris.*

1097b. Apparatus, by **M. Dulong** and **Petit,** for measuring the **Dilatation** of **Mercury** with overflow thermometer.
Polytechnic School, Paris.

1098. Effects of Heat on Nature. 9 Sénarmont crystals for heat. *Laurent.*

1100. Automatic Fire Extinguisher and Alarm. For ships, factories, and all places where steam apparatus is employed.
Sanderson & Proctor.

The action of the apparatus is as follows :—

Thermometers are fixed on the ceiling or elsewhere in the room, and are set to complete an electric circuit at a given degree of heat, each thermometer being in connexion with a galvanic battery and electro-magnet. A steam valve is also fixed in the room, communicating with the valve at the boiler. As soon as a fire breaks out, and raises the temperature of the nearest thermometer to the given degree, the electric current is complete, and the electro-magnet, by a very simple contrivance, opens the steam valve in the room and the valve at the boiler, the steam rushes into the room at the existing pressure of the boiler, envelops the flame, and, by well-known chemical laws, effectually extinguishes the fire. Simultaneously with the action of the electro-

magnet, an electric alarm and indicator are set in motion, thus giving prompt notice of the fire, and indicating its position.

1101. Prism of Rock Salt, 50 × 60 mm.
W. Steeg, Homburg vor der Höhe.

1102. Lens of Rock Salt, 75 mm. thick, and 300 mm. in radius. *W. Steeg, Homburg vor der Höhe.*

1103. Plate of Rock Salt, 60 × 60 mm.
W. Steeg, Homburg vor der Höhe.

1104. Diagram of the **Thermodynamic Relations of Aqueous Vapour** for pressure up to 30 atmospheres.
Oberbergrath E. Althaus, Breslau.

These diagrams have appeared on a smaller scale, and joined to a memoir entitled : The Boiler Systems for High Pressure, and their Application to Mining Engines, Part III., in the " Zeitschr. für das Berg-, Hütten-, und " Salinenwesen, im Preussischen Staate. Heraung. im Minist. für Handel, " Gewerbe, und öffentliche Arbeiten. XXIII. Bd., 5 Lief."

1104a. Two Photographs, representing the **Thermo-ventilator** when open and closed. *M. Wellesen, Christiania.*

This instrument, which is useful as a means of promoting health, consists of five parts, comprising a regulating balance for heat, and a valve for fresh air, which is self-closing, and can keep out the cold. The smaller part of the iron and brass tube (to which a foot or stand is fixed for exhibiting purposes) gives a clear idea of the system by which the thermo-ventilator is applied to the internal orifice of the atmospheric tube.

1105. Apparatus of sheet metal, constructed by the exhibitor, for demonstrating the **Causes of Disturbances in the Draught in Chimneys,** as well as the influence of wind and weather. It is at the same time a means of studying the general motion of air produced by heat (ventilation). Compare the adjoined description. *Prof. Dr. Meidinger, Carlsruhe.*

1105a. Apparatus for quickly communicating a **Determined Temperature** to a **Liquid,** and to maintain it at this temperature.
W. Gloukhoff, Warden of Russian Standard Measures.

It is used by a hydrostatical determination of density of the liquids; by verification of alcohometers, hydrometers, &c.; at normal, or any other temperature. The principal part of this apparatus is a cylindrical metallic stirrer, immersed in the liquid to be experimented upon, contained in a very solid glass cylinder. The warm or cold water, poured in small quantities, in the interior hollow space of the stirrer, by means of a glass funnel introduced in one of the two metallic tubes communicating with the hollow space, and a few movements up and down of a stirrer, will very quickly warm or cool the liquid, and thus bring it to a determined temperature. The syphon, introduced in another tube, serves to empty the stirrer. In the glass disk covering glass cylinder are two apertures: the large one, for weighing solid bodies in liquids, immersing in it the hydrometers, &c.; and the small one for a thermometer to determine the temperature of the liquid.

1105b. Apparatus for keeping a **Constant Temperature** in an air or water bath.

The Secondary Government School at Assen (*Netherlands*).

This gas regulator, constructed after the design of Dr. A. Van Hasselt, teacher at the school for middle-class education at Assen (Netherlands), is principally made by J. Van Rossum, servant in the laboratory.

The air thermometer, connected with the regulator and with a large Bunsen cell, is partially filled with mercury, so that only the upper bulb and a great part of the tube contain air.

When the desired temperature has been acquired, the wire of platinum is screwed down, so as to reach the mercury, at which moment a current from the cell passes. This current passes through the wire, which is coiled round the iron tube in the apparatus, through which the gas is flowing, and which is used as an electro-magnet.

The little iron valve on the side of the tube, covered with a thin plate of caoutchouc, which now shuts the tube, has a small aperture, which lets pass gas enough to prevent the lamp from being extinguished.

SECTION 9.—MAGNETISM.

WEST GALLERY, GROUND FLOOR, ROOM F.

I. NATURAL MAGNETS.

1106. Great Natural Magnet; the largest known. *See* Lamont, "Handbuch des Magnetismus," 1867, p. 107.

Teyler Foundation, Haarlem.

Weight, with the armature - -	152 kilograms.
Force - - - - -	114 "

1107. Natural Magnet, mounted in brass case, with steel poles, and soft iron keeper. *Elliott Brothers.*

1107a. Natural Loadstones (two), Russian, in perforated and painted metal cases. *Bennet Woodcroft, F.R.S.*

1107b. Siberian Loadstone and Spark Apparatus. This was the loadstone employed by Faraday in his experiments on magneto-electric induction, from which he first obtained the induction spark. (*See* Exp. Researches, vol. II.)

Museum of King George III., King's College.

II. PERMANENT ARTIFICIAL MAGNETS.

1108. Collection of Artificial Magnets, lately forged by Mr. Van Wetteren, and magnetised at Teyler's Museum.

Teyler Foundation, Haarlem.

A. Single magnet, weight 2·17 kilogr.; greatest primitive force, 51·3 kilogr.; permanent force, 35·9 kilogr.

B. Compounded magnet. No. 3,053. Weight, 1·52 kilogr.; greatest primitive force, 36·4 kilogr.; permanent force, 27·7 kilogr.

C. Two single magnets. No. 3,003. Weight, 0·51 kilogr.; greatest primitive force, 19·5 kilogr.; permanent force, 12·4 kilogr. No. 3,005. Weight, 0·52 kilogr.; greatest primitive force, 18·6 kilogr.; permanent force, 13·7 kilogr.

A third open keeper with moveable side plates.

The box, C, forms a school apparatus, to demonstrate the effect of mutual contact of the magnets, and of the constitution of the keeper, on the distribution of free magnetism, on the weight that can be suspended, and on the deflections

of the needle produced by the magnet when open, and when more or less closed.

See the memoir of Prof. Van der Willigen, which will soon appear in the Archives du Musée Teyler.

1109. Great Artificial Magnet, forged and magnetised in 1850 by Messrs. Van Wetteren and Logemann, according to the directions of Dr. Elias, whose property it is.

Teyler Foundation, Haarlem.

Newly magnetised at Teyler's Museum.

Weight - - - - -	28 kilograms.
Primitive force - - - -	260 ,,
Permanent force - - - -	200 ,,

1109a. Large Artificial Magnet made of thin Plates.

M. Jamin, Paris.

1110. Photograph of a Horse-shoe Magnet, made by Johann Dietrich, of Basle, in 1755.

Professor Hagenbach-Bischoff, Director, The Physical Institute in the Bernoullianum, Basle.

1111. Permanent Bar Magnets (pair of), in case.

James How & Co.

1112. Compound Horse-shoe Magnet. *James How & Co.*

1112a. Series of Permanent Magnets, bar form, in wooden cases for students. *Harvey, Reynolds, and Co.*

1113. A "Logemann's" Magnet, being a powerful battery of steel-plate magnets. *Frederick Guthrie, F.R.S.*

1113a. Magnets by M. Jamin. *M. Bréguet, Paris.*

III. ELECTRO-MAGNETS AND ELECTRO-MAGNETIC ENGINES.

1114. Saxton's Magneto-Electric Machine. Copy of the original machine made by Mr. Saxton, and exhibited by him before the third meeting of the British Association, held at Cambridge in the year 1833. *John O. N. Rutter, F.R.A.S.*

This machine was made specially for the contributor by Mr. Saxton, immediately after the meeting at Cambridge, and has been in his possession ever since. It is capable of producing sparks, shocks (through the tongue), and decomposes water. It also reproduces the ordinary phenomena of electro-magnetism.

The machine is described in Daniell's "Introduction to Chemical Philosophy," 1843, p. 585, sec. 873.

1115. Large Electro-Magnet, for showing magnetism and diamagnetism. *Elliott Brothers.*

1115a. Small Electro-Magnet by M. d'Obelliane, bearing thirty times its own weight. *Polytechnic School, Paris.*

1116. Three Electro-Magnets.
The Committee, Royal Museum, Peel Park, Salford.

One of which is a circular plate, $4\frac{1}{2}$ inches diameter; another, a plate $4\frac{1}{4}$ inches square; and the third, 4 inches, with one armature; the 4-inch magnet will sustain a load of 1,400 lbs. to 1,500 lbs. Made by the late R. Roberts, C.E., of Manchester.

1117. A Powerful Electro-Magnet.
The Committee, Royal Museum, Peel Park, Salford.

Of the horse-shoe form, with an elliptical section. Made by the late R. Roberts, C.E., of Manchester.

1118. Surface Electro-Magnet made in 1840. When fully excited the armature is retained with a force of upwards of a ton.
J. P. Joule, D.C.L., F.R.S., Broughton, Manchester.

1119. Electro-Magnet, on **Joule's Construction,** mounted so as to serve for supporting weights, or for experiments on Diamagnetism. *Made and exhibited by Dr. Stone.*

1120. Tubular Electro-Magnets.
John Faulkner, Manchester.

In this system iron cases are used, of such size and thickness as ensures the utilisation of the maximum force of magnetism.

The object is to accumulate and utilise all or a portion of the electric power, and thereby when desirable prevent the loss of force that takes place in electro-magnets usually employed in electrical appliances.

1121. Diagrams, illustrating the **Great Waste** of **Power** in **Electro-Magnets** as heretofore made, and the economy of tubular electro-magnets. *John Faulkner, Manchester.*

These diagrams are produced by scattering iron filings upon paper, prepared with paraffin, placed above ordinary electro-magnets and improved electro-magnets respectively.

1122. Objects illustrating the applications of tubular **Electro-Magnets.** *John Faulkner, Manchester.*

1. A. Electro-magnets; various.
2. B. Electric bells; various.
3. C. ,, indicators; various.
4. D. ,, semaphore actuators; various.
5. E. ,, telegraph sounders; various.
6. ,, ,, ,, key and sounder on one base.
7. ,, ,, ,, ,, ,, separate.
8. ,, ,, ,, sounder with movable cover.
9. ,, ,, ,, ,, with movable core.
10. ,, ,, ,, ,, with movable coil.
11. F. ,, brass and iron separators.
12. G. ,, pottery glaze iron extractors.

1123. Froment's Engine. An electro-magnetic machine depending upon the successive attraction by fixed electro-magnets of bars of soft iron fastened on a wheel and parallel to its axis.

Frederick Guthrie, F.R.S.

The successive magnetization and demagnetization of the magnets is effected by the action of cams on the axis of the wheel, which lift ivory rollers, and so displace springs to which they are fastened.

1124. Helmholtz's Electro-magnetic Engine.

F. Rob. Voss, Berlin.

The advantage of this machine is that it is set in motion by a very small galvanic force; with two Bunsen elements it will drive one of Professor Helmholtz's double-syrens or one of his centrifugal commutators.

Professor Helmholtz has applied a contact-arrangement to the commutator of the Siemens' bobbin, which surpasses all former ones in that it avoids great surfaces of friction, and so greater power and speed is attained.

This is a new instrument, and consists of an insulated plate covered with tinfoil, on which is screwed a metal ring, inside this a glass ball runs about; one pole of an electric machine is in contact with the tinfoil, and the other pole with the metal ring; when the current passes the ball runs about.

1124a. Electro-magnetic Machine, with velocity regulator. Helmholtz.

Physical Institution of Berlin, Prof. Helmholtz.

The current which drives the electro-magnetic machine is interrupted by the centrifugal regulator whenever the velocity exceeds a certain limit, whereupon the driving force ceases. Using a current which is only a little stronger than what exactly suffices for the normal velocity, exceedingly constant velocities of rotation are obtained. (Described by M. Exner in the Litzungsberichte of the Vienna Academy, Math. Natura. section, Bd. LVIII., Abth. II., page 602.)

1125. Electro-magnetic Engine. *F. Stöhrer, Leipzig.*

1125a. Electric Motive Power, acting on a pump

M. Loiseau, junior, Paris.

1125b. Electric Motive Power, acting on a jet of water.

M. Loiseau, junior, Paris.

1125c. Electric Motive Power, acting upon a hammer.

M. Loiseau, junior, Paris.

1125d. Electric Lighting Apparatus.

M. Loiseau, junior, Paris.

1125e. Electric Telegraph. *M. Loiseau, junior, Paris.*

1125f. Electro-Magnetic Machine, invented by Sir Charles Wheatstone.

Wheatstone Collection of Physical Apparatus, King's College, London.

1125g. Electro-Magnetic Engine, patented by Thomas Allan, No. 14,190, A.D. 1852; and No. 2,243, A.D. 1854.

Lent from the Patent Office Museum by the Commissioners of Patents.

This engine is so constructed that when set in action several electro-magnets are formed one after the other, and give successive impulses in the same line or direction to an upright rod or bar, capable of being moved longitudinally to any desired extent.

1125h. Electro-Magnetic Machine, invented by Sir Charles Wheatstone.

Wheatstone Collection of Physical Apparatus, King's College, London.

1125i. Electro-Magnetic Machine, invented by Sir Charles Wheatstone.

Wheatstone Collection of Physical Apparatus, King's College, London.

IV. APPARATUS FOR INVESTIGATIONS CONNECTED WITH PHENOMENA OF MAGNETISATION.

1126. Apparatus showing a remarkable property of magnetised Soft Iron Tubes.

Professor Dr. A. von Waltenhofen, Prague.

On a balance are suspended a tube and a solid cylinder, both of soft iron, the cylinder being much heavier, and therefore counterbalanced by adding a brass weight to the tube, or by filling it with shot. Both tube and cylinder are introduced into an electro-magnetic helix, fixed upright beneath the balance at the bottom of the apparatus (as in the electro-magnetic balance of Becquerel). The coils are joined so as to unite the poles of a Bunsen's cell, or any other voltaic cell of unimportant resistance.

On completing the circuit, a suction force is exerted on the tube and the cylinder, tending to draw them into the helices. The tube or cylinder will then appear the heavier, according as the electric current possesses less or more strength. This change can be performed at pleasure by means of a Wheatstone's rheostat, introduced in the path of the current.

The theory of this phenomenon is given in the Sitzungsberichte d. k. Akademie d. Wissenschaften. Juli Heft, 1870.

1126a. Apparatus by Mr. Th. Petroucheffsky, Professor at the University of St. Petersburg, for **measuring** the distance of the **Magnetic Poles** in straight magnets from their ends.

Imperial University of St. Petersburg.

A straight magnet is suspended horizontally at a point where one of the poles is approximatively supposed to be. Another straight magnet, much shorter than the first, is placed in the same horizontal plan, perpendicularly to the suspended needle. A slow movement can be given to this second magnet along a divided rule, horizontal and parallel to the suspended needle.

The mutual (repulsive) action of the two magnets is greatest when the lengthening extension of the small magnet passes by the magnetic pole sought, provided that the suspended magnet remains perpendicular to the second magnet. To fulfil this condition an auxiliary magnet is used, which is placed on the other side of the suspended magnet, and which is to produce an equal, but contrary, effect to the second magnet. This method of finding out the poles has been described in Russian in the "Messenger of Mathematical Sciences" (Wiestin), and since, in Poggendorff's Annalen, Bd. 152, s. 42. It demands the use of three distinct apparatus: 1st. A "bifilaire" (double thread wire) apparatus for suspending cylindrical magnets. 2nd. A measuring apparatus, having a small magnet that can be moved along the apparatus, while keeping perpendicular to the direction of said movement. The apparatus has two divisional rules, and is supplied with a microscope, two levels, and two small telescopes of short focus. These two apparatus are placed alongside, and parallel to one another, and, approximately, in the magnetic meridian. The third (No. 3) apparatus consists of a divisioned rule placed perpendicularly to the suspended magnet. Along this apparatus may be moved a small magnet, of which the function has been explained above. The second of the apparatus enumerated has been constructed by Mr. Brauer, of St. Petersburg, from the designs of Professor Petroucheffsky.

1126b. Apparatus for so-called "**Normal**" **Magnetism,** by Mr. Th. Petroucheffsky, Professor of Physics at the University of St. Petersburg. *Imperial University of St. Petersburg.*

An iron cylinder for magnetising, placed symmetrically in a magnetising screw, may receive very different distributions of the free magnetism, according to the length of the screw, but the distribution does not depend on the strength of the current. The inventor has discovered that the distribution of the remanent magnetism, or rather the interpolar distance, stands always the same, independently of the length of the screw or the strength of the current. At a fixed length of the screw, the magnetic poles of the electro-magnet and the poles of the remanent magnetism coincide, so that the electro-magnet, placed horizontally and perpendicularly to the magnetic meridian before a sensitive magnetic needle, acts upon it in the fixed direction (say, the direction of the meridian itself) during the circulation of, and after the cessation of, the current; in the latter case, the poles of the remanent magnetism act. The poles are then almost at the ends of the magnetising spiral, the length of which is about 0·8 of the iron cylinder, independently of the length and diameter of the cylinder. This arrangement of the poles of the electro-magnets is called "normal." The apparatus used in these researches are composed of two very distinct parts. The first apparatus contains two brass cylinders, surrounded with wire spirals; by turning one of these cylinders, the number of spirals can be lessened on the one, and increased on the other. Inside one of these cylinders the iron to be experimented upon is placed. This apparatus is set upon a table covered with marble plates moving in two directions, perpendicular to one another. The other apparatus is a needle, called "unipolar," suspended by means of a cocoon thread, with two microscopes.

1127. Ring of Elias for magnetising artificial magnets of large size. *Teyler Foundation, Haarlem.*

A magnet of 28 kilogrammes weight has been recently magnetised by this ring in Teyler's Museum.

Dr. Elias proposed more than 25 years ago his ring-coil for the production of artificial magnets of all dimensions, by an intense galvanic current. His

artificial magnet here exhibited has lately been re-magnetized, with a slight modification of his method by Prof. Van der Willigen in the Teyler Museum, by this ring with the current of forty Bunsen elements of the usual large size.

1128. Apparatus for showing to an audience the effects of the superficial tension of liquids (Tomlinson's Cohesion Figures); **Magnetic Curves** or the movement of liquid films, &c.
Prof. W. F. Barrett.

1129. One Bar of Metallic Nickel, 20 inches long and ½ inch diameter. *George Gore, F.R.S.*

1130. Three Plates of Metallic Nickel, 6 inches long and 1½ inch wide. *George Gore, F.R.S.*

1131. One Small Nickel Horseshoe, for making a Nickel Magnet. *George Gore, F.R.S.*

1132. One Plate of Metallic Cobalt, 6 inches long and 1½ inch wide. *George Gore, F.R.S.*

1135. Horse-Shoe Magnet of **Nickel,** used by Sir William Thomson in his experiment on the effect of magnetism on the thermo-electric quality of nickel. Result published in the Transactions of the Royal Society for the year 1856, Bakerian Lecture.
Edinburgh Museum of Science and Art.

1136. Apparatus for showing a series of molecular and magnetic changes in a red-hot iron bar; and designed also to show the influence of traction, compression, and torsion upon such changes. The latter experiments have not yet been made with it.
George Gore, F.R.S.

See Philosophical Magazine, Sept. 1870.

1136a. Apparatus for exhibiting molecular changes occurring during the heating and cooling of iron wire.
Prof. W. F. Barrett.

1136b. Apparatus designed by G. Gore, F.R.S., for exhibiting the effects of stress upon the magnetisation of iron.
Prof. W. F. Barrett.

1136c. Gore's Apparatus for exhibiting the torsion of an iron wire produced by axial and transverse magnetisation.
Prof. W. F. Barrett.

1136d. Class Apparatus for exhibiting the elongation of unstrained iron produced by magnetisation. *Prof. W. F. Barrett.*

1137. Coulomb's Torsion Balance for magnetic and electric observations. *Warmbrunn, Quilitz, and Co., Berlin.*

1138. Apparatus for the **demonstration** of **Magnetic Friction,** constructed by the late Mr. Kleemann in Halle.

Prof. Dr. Dove, Berlin.

V.—APPARATUS FOR INVESTIGATIONS CONNECTED WITH DIAMAGNETISM.

1139. Glass Tubes prepared by **Faraday** for testing the magnetic and diamagnetic character of **Gases.**

The Royal Institution of Great Britain.

The tubes containing the gas to be examined were suspended in the magnetic field of a powerful magnet, the result being either attraction or repulsion of the tubes as the gases they contained were either magnetic or diamagnetic.—Phil. Trans., 1850.

1140. Bars of Borate of Lead Glass, made and used by **Faraday,** for the action of magnets on polarized light.

The Royal Institution of Great Britain.

Phil. Trans., 1845.

1141. The Diamagnetic Box of Michael Faraday, containing spheres, cubes, and bars of diamagnetic metals; tubes of various liquids, bars of borate of lead, glass, various crystals, cradles, supports, &c., used by Faraday in his researches on diamagnetism. *Professor Tyndall, F.R.S.*

1142. Instrument used in researches on the **Polarity** of the **Diamagnetic Force.** *Professor Tyndall, F.R.S.*

Phil. Trans., 1856.

1143. Specimen of "Faraday's Heavy-glass."

George Gore, F.R.S.

1144. Electro-Magnet for Induction and Diamagnetic Experiments, made in 1850, of a broad plate of iron, so as to obtain the largest possible inductive power from the conducting wire. *James P. Joule, D.C.L., F.R.S.*

The coil is composed of a bundle of copper wires, and has a resistance about equal to that of a Daniell's cell, exposing a surface of one foot square.

1144a. A large diamagnetic Apparatus, with glass case, rods, &c. *Warmbrunn, Quilitz, & Co., Berlin.*

VI.—APPARATUS FOR THE OBSERVATION AND REGISTRATION OF THE TERRESTRIAL MAGNETIC ELEMENTS.

DIP AND INTENSITY INSTRUMENTS USED IN MAGNETIC SURVEYS ON SHORE AND AT SEA.

Exhibited by the Admiralty—Hydrographic Department.

1145. Dip Circle for observations at sea, fitted with special arrangements for finding the magnetic meridian. By Nairn and Blunt; date, 1772–1834.

This instrument may be considered as intermediate in construction between that made by Nairn for Captain Phipps, in his voyage towards the North Pole in 1773, and the Fox circle introduced by Mr. R. W. Fox in 1834, hereafter described.

It is suspended by an universal joint, from a wooden stand carrying one adjusting screw. The needle, 9 inches long, with steel axles, vibrates within a circle graduated to 20′, and the ends of the axis are fitted to work in the agate holes of two adjustable screws in the vertical bars supporting the circle, and otherwise strengthening the instrument. The sliding pointers on the graduated circle are intended to be adjusted to the mean position of the needle when the motion of the vessel causes it to vibrate on either side of the dip. The screw on the under side of the circle works the metal supports on which the needle is placed until adjusted in the agate holes. A thermometer graduated to 38° is placed inside the instrument.

The peculiar arrangement for ascertaining the magnetic meridian consists of a small compass gimballed at the end of a wooden arm. The other end of this arm has a brass fitting to fix on pins in the graduated circle on the top of the frame. The motion of the arm in azimuth causes the whole apparatus to move in the wooden stand until the Dip Circle is in the magnetic meridian, as indicated by the compass.

1146. Dip Circle and Intensity Apparatus. Fitted with arrangements for ascertaining the magnetic meridian by three methods. By Dollond; probable date, 1776–1834.

The Dip Circle is made after the pattern described by the Hon. Henry Cavendish in the Phil. Trans., vol. xlvi., in which the dipping needle rolls upon horizontal agate planes, and a contrivance is applied for lifting it off and on to the agates at pleasure. A milled headed screw works this lift, and an adjacent butterfly screw, an arrangement for causing the needle to vibrate. The vertical circle is graduated to 20′; the outer circle of the base plate is also graduated to every 45°.

The direction of the magnetic meridian may be ascertained by two methods other than that usually adopted:—1. An edge bar horizontal needle fitted with an agate cup may be placed on the steel point fixed to a balanced axis provided for placing on the agates like the dipping needles. The coincidence of this needle with the plane of the vertical circle shows the latter to be in the magnetic meridian. 2. The same edge-bar needle can be placed on a pivot screwed in the centre of the graduated circle at the bottom of the travelling box.

Of the three dipping needles, two are flat and one cylindrical and sharply-pointed. The axes are made of gun metal, and one of the flat needles is fitted with a brass cone on Mayer's principle.

Intensity Observations.—For this purpose the box which carries the dip circle is fitted with two apertures filled with glass, and a torsion circle on the tòp. The two flat needles, one of gun-metal for eliminating tension, and the other for horizontal vibrations, have metal pins screwed into the centres by means of which they are attached to the stirrup suspended by silk fibres from the torsion circle. The vibrations are observed through the glass sides, and the magnetic meridian by the edge-bar horizontal needle before described.

This apparatus closely resembles that used by David Douglas on the north-west coast of America and the Sandwich Islands in 1829–34.

1147. Dip Circle. By Robinson; date, 1830–75.

In this circle the needles are 6 inches long, flat and pointed. They move on agate planes in the centre of a graduated circle, and observations are read off by means of lenses fixed in the ends of a moveable arm centred on one of the glass sides of the instrument.

The advantages of this form of dip circle are:—1. That both the needles can be read off for nearly every angle of dip. 2. Portability, from compactness of stowage in the box, as the vertical circle is fitted so as to be readily detached from the horizontal.

An instrument of this kind was used by Major Estcourt during the survey of the river Euphrates in 1836.

1148. Dip and Intensity Circle invented by R. W. Fox, F.R.S. By Mr. George, of Falmouth; date, 1834–75.

The principal object of this instrument is the observation of Dip and Intensity at sea, and when placed on a properly constructed gimballed table this can be accomplished, except in very bad weather.

The needles are flat, tapering from the axis to a point, and 6·9 inches long. The axles are finely pointed, and work in the jewelled holes fitted to the bracket and centre of a concentric disc in the back of the instrument, which also carries the bracket. The grooved wheel on the axis is used for carrying the hooks and deflecting weights in intensity observations. In the holes in the cross arms of the verniers at the back of the circle, the deflectors, N and S, are screwed for dip and intensity observations, and are set at any required angle by means of the graduated circle. Of the two large thumb screws in the back of the moveable disc, one works the bracket when mounting the needle and vice versâ; the other works the clamp. At other times they are used in conjunction for the purpose of moving the disc when altering the bearings of the needles in the jewels. The pointed projection between these screws, when rubbed by the ivory disc, opposes the effect of friction in the needle and jewels.

The needles are packed in metal cases with screw ends, and may thus be used as deflectors.

Instruments of this construction have been largely and successfully used in the various magnetic surveys made at sea in H.M.'s ships.

1149. Hansteen's Intensity Apparatus; date, 1819–50.

This form of intensity apparatus is that first adopted by M. Hansteen in his magnetic survey of Norway and the Baltic shores in 1819–24, and since largely used by various observers. The vibrating needle is cylindrical, pointed at the ends, 2·65 inches long and 0·15 inches in thickness. It is suspended from the moveable pulley at the end of the brass tube by a fibre or silk secured to a brass strap and loop in its centre. By means of the pulley the needle can be adjusted to the required height in the vibrating box.

The value of the observations depends on the permanency of the magnetic condition of the needle.

1150. Portable Magnetic Dip Circle, $3\frac{1}{2}$ in. needle, made for, and used by, the late Sir John Shuckburgh. The dividing is very fine, and believed to be Ramsden's. *G. J. Symons.*

GENERAL.

1176. Photograph of an Inclinatorium, by Daniel Bernoulli, completed by Johann Dietrich of Basle, in 1751.
Professor Hagenbach-Bischoff, Director, The Physical Institute in the Bernoullianum, Basle.

This instrument gained the Prize of the Academy of Paris in 1743.

1177. Dip Circle, for determining the magnetic inclination, adapted to needles of various lengths. (Barrow, London.)
H. Lloyd, Trinity College, Dublin.

1178. Theodolite Magnetometer, 9-inch circle, and collimator magnets. (Jones, London.)
H. Lloyd, Trinity College, Dublin.

1179. Dip Circle or inclination compass. *James How & Co.*

1180. Terrestrial Magnetism Magnetometer, new pattern, constructed to determine the magnetic moment of a magnet, and the direction and intensity of the magnetic force at a given place. *Elliott Brothers.*

The instrument consists of two distinct parts. For the observations of the deflection magnet, the copper box screwed to the centre of azimuth is used; underneath this passes, through the centre, a divided metal bar with a vernier carrying a magnet; at right angles to this bar is the observing telescope. The hollow vibration magnet, with a scale on glass at one end and a collimating lens at the other, is observed through another telescope. The latter magnet is suspended in the mahogany box above the copper box.

1184. Declinatorium for sea and land observations.
Carl Bamberg, Berlin.

The instrument is furnished with gimbals for use at sea, and may be fixed for observations on land. The magnetic system, which is provided with a speculum, is constructed for reversal, and oscillates upon a point; the adjustment is effected by means of a collimator telescope, and orientation from terrestrial and astronomical objects.

1185. Deviation Magnetometer, for determining the magnetic relations on iron vessels. *Carl Bamberg, Berlin.*

The deviation magnetometer enables determinations of deviation (declination and inclination) to be read off on points, and also determinations of horizontal and vertical intensity by oscillations and deviations. A small telescope serves for orientation by terrestrial and astronomical objects. The instrument may be mounted on the same stand as the compasses.

1190. Drawing of a Dip Circle. *J. P. Joule, F.R.S.*

The needle, constructed of a thin ribbon of annealed steel, weighing 20 grains, is furnished with an axis made of a wire of standard gold. This axis is supported by threads of the Diadema Spider attached to the arms of a balance suspended by a fine stretched wire. The whole is hung by a wire which can be twisted at the head through 180°. At the bottom is attached a paddle immersed in castor oil, which brings the instrument speedily to rest in a fresh position. The deflections are read off by a short-focus telescope, placed on an arm revolving on an axis in the centre of the circle. With this instrument the dip can be determined within the fraction of a minute of a degree in less than a quarter of an hour.

With this drawing is exhibited a specimen of the Thread of the Diadema Spider, also Thread of the Diadema Spider Cocoon.

1191. Portable Unifilar Magnetometer. An instrument for determining the horizontal intensity of terrestrial magnetic force; and also the declination.

Kew Committee of the Royal Society, Kew Observatory.

It consists of two parts: one for determining the time of vibration of a suspended magnet; the other for determining the amount of deflection it produces when caused to act upon a second needle.

In addition there is a third magnet, which is subsequently suspended, and its position referred to the astronomical meridian, by means of a mirror, which serves to allow of an observation of the sun's azimuth being made.

Used by the Rev. S. J. Perry, F.R.S., during the late Transit of Venus Expedition to Kerguelen.

1192. Two 12-inch Dipping Needles. *Royal Society.*

1193. Kew Pattern Dip Circle.

Kew Committee of the Royal Society, Kew Observatory.

Dip circle of the pattern adopted by the Kew Observatory, having needles 3½ ins. long, which are read by microscopes, carried by a circle in front of the needle frame. It is also provided with accessory needles, for determining total force, after the method of Dr. Lloyd.

1196. Portable Theodolite for the observation of the **Magnetism of the Earth,** constructed by Dr. Meyerstein, Göttingen.

Prof. Dr. A. Kundt, Strasburg.

1197. Edelmann's graduated Telescope for reading reflecting instruments (small). *M. Th. Edelmann, Munich.*

1198. Edelmann's graduated Telescope for reading reflecting instruments (large). *M. Th. Edelmann, Munich.*

1199. Edelmann's graduated Telescope for two observers.

M. Th. Edelmann, Munich.

1200. Edelmann's Rider belonging to the graduated telescopes for observing two objects at the same time.

M. Th. Edelmann, Munich.

1201. Edelmann's Declination Magnetometer.
M. Th. Edelmann, Munich.

1202. Edelmann's Variation Instrument for **Declination.** *M. Th. Edelmann, Munich.*

1203. Edelmann's Variation Instrument for **Horizontal Intensity.** *M. Th. Edelmann, Munich.*

1204. Edelmann's Variation Instrument for **Vertical Intensity.** *M. Th. Edelmann, Munich.*

1205. Edelmann's Magnetometer for declination, vertical and horizontal intensity. *M. Th. Edelmann, Munich.*

1206. Portable Magnet Theodolite.
M. Th. Edelmann, Munich.

1207. Weber's Earth Inductor, new construction.
M. Th. Edelmann, Munich.

1207a. Book, containing special treatises on some of the above instruments. *M. Th. Edelmann.*

1207b. Book, containing the description of the above-named apparatus. *M. Th. Edelmann.*

1209. Photograph of **Gauss's Bifilar Magnetometer.**
Magnetic Department of the Observatory in Göttingen, Prof. Dr. Schering.

1210. Photograph of the **observing Telescope,** belonging to the above.
Magnetic Department of the Observatory in Göttingen, Prof. Dr. Schering.

1211. Photograph of **Gauss's Earth Inductor.**
Magnetic Department of the Observatory in Göttingen, Prof. Dr. Schering.

1212. Photograph of the **Needle and Multiplier.** (Unifilar Magnetometer belonging to the above.)
Magnetic Department of the Observatory in Göttingen, Prof. Dr. Schering.

1213. Photograph of the **Torsion Needle** with stop.
Magnetic Department of the Observatory in Göttingen, Prof. Dr. Schering.

1214. Photograph of the **Theodolite** for the determination of the **absolute Declination.**
Magnetic Department of the Observatory in Göttingen, Prof. Dr. Schering.

1215. Description of the above-named instruments; Gauss's Works, vols. 1–7.

Magnetic Department of the Observatory in Göttingen, Prof. Dr. Schering.

1216. Dipping Needle with microscopes for the observation of the needle points, constructed by Dr. Meyerstein in 1843.

Magnetic Department of the Observatory in Göttingen, Prof. Dr. Schering.

1217. Microscopic Apparatus for the determination of the **Collimation** of **Dipping Needles,** constructed by Dr. Meyerstein in 1843.

Magnetic Department of the Observatory in Göttingen, Prof. Dr. Schering.

1218. Reflecting Dipping Needle, after Dr. Meyerstein.

Physical Institute of the University of Göttingen, Prof. Dr. Riecke.

The instrument is so constructed that the magnetization can be effected either by touching with a steel magnet, or by means of electric spiral. In order to carry out the latter, the case is gently taken off and the spiral pushed over pillar and needle.

1219. Model for the illustration of the **Deviation** in **Iron Ships,** after Neumeyer, constructed by the Joint-stock Company for the Manufacture of Meteorological Instruments, formerly Greiner and Geissler.

Hydrographical Department of the Imperial Admiralty, Berlin.

This model represents an important apparatus of instruction, which illustrates all the phenomena of deviation and compensation of the compasses. The apparatus is in use in the institutions of the Imperial Navy, the stations of the Naval Observatory, and schools of navigation.

1220. Gauss's Magnetometer, constructed by Breithaupt and Son, in Cassel, with apparatus for suspension.

Polytechnic School in Cassel, Dr. Gerland.

The instrument has been constructed, according to the instructions and under the supervision of Professor *W. Weber* in Goettingen, by Messrs. *Breithaupt and Son.* Since the magnetometer with which *Gauss* and *Weber* had carried out their magnetic labours, and which is identical with the one here exhibited, has not been sent to London, this instrument may be considered as one of the oldest of its kind in the present exhibition.

1221. Photographic self-registering Horizontal Force, or **Bifilar Magnetometer,** constructed in 1847, at the Kew Observatory, by Mr. Francis Ronalds.

Kew Committee of the Royal Society, Kew Observatory.

Described in the British Association Report for 1849.

The magnet, 15 inches long, is suspended in a loop of fine wire, by means of a pulley, forming a bifilar arrangement. It carries, attached to its lower

side, a light brass bar, which moves a little shutter in front of an oil lamp, allowing a pencil of rays to pass through a hole in it. The light is then thrown, by means of a lens, upon a daguerreotype plate, which is steadily drawn upwards by means of a clock.

The curves upon the daguerreotype plates were sometimes etched in, and engravings subsequently worked off, or tracings were made upon sheets of gelatine, which, being preserved, allowed the silvered plates to be repeatedly used.

This instrument was superseded by the improved magnetographs erected at Kew by Mr. Welsh in 1857, which have since remained in almost continuous action.

The suspension frame originally fitted has been replaced by one not belonging to the instrument when in use.

1222. St. Helena Magnetometers.

(1.) Declinometer instrument and telescope, used at St. Helena, 1840–1849.

(2.) Bifilar magnetometer and telescope, used at St. Helena, 1840–1849.

(3.) Vertical force magnetometer, used at St. Helena, 1840–1849. *Kew Committee of the Royal Society, Kew Observatory.*

The three magnetometers, the declination, horizontal force, and vertical force instruments, respectively, were made by Grubb, of Dublin, and formed one set of those used in the Colonial Magnetic Observatories, founded by the Government in 1840. The instruments were described in the Report of the Royal Society Committee of Physics, &c.

These instruments were erected at St. Helena in 1840, and constantly observed from that date until 1849.

The declinometer consists of a magnet bar, suspended by fibres of untwisted silk, and carrying a collimator arrangement of lens and scale, the whole being enclosed in a cylindrical casing, perforated with windows, through which the scale is viewed by means of a telescope.

The bifilar is a somewhat similar arrangement, but the support of the magnet is formed of two parallel wires, which are twisted so as to bring the magnet into a position at right angles to the meridian.

The vertical force magnetometer is a light magnet 12 inches long, carrying a brass frame with cross wires at each end ; it is supported by a steel knife edge, bearing on agate planes, and its movements are observed by microscopes, fitted with micrometers, by which the position of the cross wires on the magnets is read.

1223. Declination Compass, used by Sir J. Richardson and Capt. Pullen.

Kew Committee of the Royal Society, Kew Observatory.

It consists of a square glazed box, containing a compass card, which is formed of a light metal divided circle, and two spring needles, connected to an agate cup in the centre. This is mounted so that it can either be suspended by a silk thread, or rest upon a point in the ordinary manner.

Two microscopes are fixed vertically above it, so that the divisions on the circle may be read by them, concave metallic reflectors being fitted to them for the purpose of illuminating the scale at the time of reading off.

1224. Portable Apparatus for **vibrating** a **Magnet,** used by Capt. Barnett, in H.M.S. "Thunder," in 1841.

Kew Committee of the Royal Society, Kew Observatory.

It is a glazed box 4 inches square, standing on a levelling stand, and carrying a brass suspension tube 6 inches in length. It also has an ivory circle fixed to its bottom.

There are two magnets 2·7 inches long, each of which when not in use is kept in a separate little copper box, where, fitted to an armature, it is embedded in iron filings.

1225. Dip Circle used by **Sir James C. Ross.**

Kew Committee of the Royal Society, Kew Observatory.

A Robinson dip circle, with four 6-inch needles, supported on agate planes, and read off direct on the circle of the instrument.

1225a. Apparatus for **discovering the Magnetic Poles** in Magnets and Electro-Magnets, by Professor Th. Petroucheffsky.

Imperial University of St. Petersburg.

A fine metal wire is stretched within the magnetic meridian, above a sensitive marine compass. Within a distance of $0 \cdot 6^{m}$ from the compass, the pole of which is to be determined, and below the same wire, a magnet is placed, so that its two arms are horizontal, and perpendicular both to the meridian and to the wire. The loaded needle of the compass usually deviates through the effect of the magnet, but in a special case it may be made to remain within the plane of the meridian. To effect this the line passing through the two curved magnet poles must pass also within the plane of the meridian, a thing easily accomplished. In the case of electro-magnets, besides the two bobbins forming part of the electro-magnet, a third bobbin is used, intended to compensate the effect of the first two upon the loaded needle. The description of this method, which presumes that both poles are equi-distant from the extremities of the magnet, as also the results of experiments, are published in the Russian work "Cours de Physique Expérimentale," by M. Petroucheffsky and Suise, in the "Annalen der Physik," by Poggendorf.

1226. Forbes' Hemispheres for illustration of Lectures on the Earth's Magnetism (G.), and Temperature (F.)

University of Edinburgh.

See printed descriptions enclosed.

1227. Gambey's Declination Compass.

Conservatoire des Arts et Métiers, Paris.

1228. Self-registering Bifilar Magnetometer, with apparatus for determining the temperature-correction of the magnets employed in several automatic instruments, from the displacements of the photographic trace due to observed changes of temperature.

Chas. Brooke, F.R.S.

1229. Self-recording Magnetometer.

Chas. Brooke, F.R.S.

Rough home-made apparatus, by which the first automatic records of magnetic variation by reflected light were obtained. The cylindrical lenses are water-lenses.

1229a. Self-registering Balanced Magnetometer, with compensation for changes of temperature, and warm water envelope for testing the same. The compensation is effected by the weight of the column of mercury in a thermometer tube.

Chas. Brooke, F.R.S.

1229b. A self-registering Barometer.

Chas. Brooke, F.R.S.

1229c. Photographic Apparatus, for registering simultaneously the variations of both the above instruments.

Chas. Brooke, F.R.S.

1229d. Self-registering Bifilar Magnetometer, with compensation for changes of temperature, and warm-water envelope for testing the same. *Chas. Brooke, F.R.S.*

The compensation is effected by diminishing the lower interval of the double suspension, by means of the differential expansion of glass and zinc, in proportion to the diminished magnetic energy of the bar, due to elevation of temperature.

Photographic apparatus for registering the variation of the above, by means of a reflected pencil of light.

1229e. Apparatus for showing the longitudinal vibrations of a row of particles, (1) stationary, and (2) progressive.

Chas. Brooke, F.R.S.

The vibrations shown are those constituting the first harmonic subdivision of a pipe closed at one end.

1230. Photographic self-registering Declination Magnet, constructed in 1846, at the Kew Observatory, by Mr. Francis Ronalds.

Kew Committee of the Royal Society, Kew Observatory.

Described in the Philosophical Transactions for 1847, vol. I.

The magnet, 2 feet long, when in use, was suspended by a silken skein, 9 feet long, on its under side; it carries a brass bar, from one end of which hangs a perforated metal plate, which, moving in front of a lamp, permits a pencil of light to fall upon a daguerreotype plate, carried slowly upwards by a clock suitably arranged.

The magnet is surrounded by a damper, made by electrotyping a frame of mahogany with copper. Both are enclosed in double wooden cases, having both surfaces covered with gold paper.

This instrument was superseded by the improved Kew magnetographs, which have been in almost continuous action since 1858.

1231. Instrument for the **determination** of the **position** of the **point** of **convergence** of the rays of the **Aurora Borealis,** both when it is below the horizon and also when it is above the horizon at the appearance of the Corona.

Professor Heis, Münster.

The ball, resting in the pan, can after a few trials be brought into such position that several diverging pencils of the aurora borealis on the northern or the southern sky are, when properly viewed, covered by the rod which

passes through the centre of the ball. The point of this rod, which can be moved up and down in the ball, shows, when the instrument is set according to the astronomical meridian, the azimuth and depth (or height) of the converging points of the aurora pencils. This point of convergence does not exactly coincide, as the exhibitor has shown at the time of the great display of aurora borealis, Feb. 4th, 1872, with the point towards which the inclination needle directs. From the deviation of the two points, the height of the aurora can be calculated.

The instrument, which is easily manipulated, is much recommended to arctic explorers.

Instrument for navigators in the Arctic Regions for ascertaining the connexion of the Northern Lights with terrestrial magnetism, and for determining the altitude of the Northern Lights. By means of an instrument designed by the exhibitor, the point of convergence of the north light rays is to be accurately determined, as well when at the appearance of the corona it is situated above the horizon, as when it is below the same, and in regard to height, depth, and azimuth. By the deviation of the point of convergence from the direction of the dipping needle, the height of the north light rays can be calculated.

1231a. Apparatus for the **Demonstration** of **Magnetic Friction,** made by the late Mechanict Kleemann, at Halle.

Prof. Dove, Berlin.

1231b. Compass with **Diamond Pin.**

Ernst Winter, Hamburg, Eimstustel.

SECTION 10.—ELECTRICITY.

WEST GALLERY, GROUND FLOOR, ROOM F.

I.—APPARATUS FOR PRODUCING AND MAINTAINING DIFFERENCES OF ELECTRICAL POTENTIAL.

a. FRICTION AND INDUCTION MACHINES.

1233. Electrical Machine, having ebonite plate 3 feet in diameter. *Frederick Guthrie, F.R.S.*

This machine gives sparks 13 inches long.

1233a. Large Electrophorus, with shellac plate, 360mm. diameter. *Warmbrunn, Quilitz, & Co., Berlin.*

1234. Carré's Electric Machine. *Prof. W. F. Barrett.*

This is an induction machine or continuous electrophorus, but the loss from the inductor is renewed by a small attached frictional machine.

1234a. Froment's Electric Pendulum.

The pendulum is kept in motion by a current passing round the electro-magnet which lifts a small weight that is released as the pendulum descends. A control clock is associated with the pendulum.

1234b. Crystal of Tourmaline, mounted to show Pyro-Electricity.

This crystal during heating or cooling exhibits polarity at its extremities. It is pivoted on a diamond cup.

1234c. Electrical Machine, by Singer, used by Mr. Francis Ronalds in his early experiments in the discovery of the electric telegraph; described in his work on the electric telegraph, dated 1823.

Kew Committee of the Royal Society, Kew Observatory.

It is an ordinary cylinder machine of blue glass, standing on glass columns.

1235. Bertsch's Machine. *Frederick Guthrie, F.R.S.*

A negatively excited sheet of ebonite leans against a revolving disc of the same material. On the other side of the revolving disc, one above and one below, are electric rakes. The conductor in connexion with the lower rake becomes negatively charged, the other one positively.

1235a. Apparatus for uniting several **Galvanic Elements** into one of large surface, so as to preserve the entire strength of the current by lessening the resistance.

Imperial University of St. Petersburg.

To effect this, two metal cylinders, each bored with seven holes parallel to the axle, and fitted with screws, are used. In one cylinder, the six ends of conductors directed by the positive electrodes (anodes) of the elements are inserted, and in the other, the six conductors direct by the negative electrodes (cathodes). The seventh hole is reserved for the conductor, the section of which is equal to the total section of the six other conductors. This last conductor issues from the side opposite to the cylinders. The apparatus here described is used by Mr. Petroucheffsky in St. Petersburg.

1235b. Large-sized Galvanometer, for demonstrating the principal effects of Ohm's formula.

Imperial University of St. Petersburg.

It consists of a strong brass ring, below which are two long plates, fitted at their extremities with an adjustment for uniting the galvanic couples parallel-wise (in quantities). Another ring, with more than 400 rounds of wire, serves to study the combination of the couples in a different way. The two rings are united together, and can be set in the very differential pointings of the hand which moves on a pivot at the centre of the cylinder, the lateral surface of which is divided into degrees. The hand is furnished with two wires crossing each other at right angles ; the four curved ends show the divisions of the cylinder.

This apparatus, for demonstration, is constructed according to the directions of Mr. Petroucheffsky, Professor in the University of St. Petersburg.

1235c. Apparatus intended for producing **Thermo-electric Currents** in a special manner.

Imperial University of St. Petersburg.

It consists of ten direct electro-magnets, joined at their curved ends, the whole forming a zig-zag. The iron blades do not touch closely, but are connected by small brass cylinders to which they are soldered at their extremities. These small cylinders carry brass plates and rods placed alternately. When the apparatus is to be used, these plates are heated approximately up to 100° centigrade ; the brass rods are cooled with crushed ice, and then the galvanic current of a six element battery (carbon, zinc, chromic liquid,) is inducted into the bobbins of the electro-magnets, odd or even numbers. The thermo-electric current thrown into the iron blades produces a strong deviation of the hand of a sensitive galvanometer, and of the wires of small resisting power.

The fact of the heterogeneousness of magnetised metals and non-magnetised metals was discovered by Mr. Thompson. The apparatus here described is constructed by Mr. T. Petroucheffsky, Professor in the University of St. Petersburg. The first experiments made with this apparatus, slightly altered however, have been briefly described in Russian in the "Journal of the Russian "Society of Chemistry," and in that of "The Physical Society of the University of St. Petersburg," Vol. 6, Section Phys., p. 107 (1874).

1236. Holtz's Machine. *Frederick Guthrie, F.R.S.*

A good example of this machine in one of its original forms, with window and armatures. It gives a current of sparks over an interval of 8 inches.

1237. Electrical Machine, based on Holtz's principle, with ebonite discs. *Dr. L. Bleekrode, The Hague, Holland.*

This machine is constructed for generating electricity on the principles of induction as first employed by Holtz. The form is very much simplified, and the only material used is ebonite (india-rubber combined with sulphur). Two forms are constructed by the exhibitor; the single ebonite machine with one fixed disc and another rotating before it, and the double ebonite machine. The latter consists of one fixed disc with paper armatures placed in the ordinary way but on both sides, a double system of conductors, and two rotating discs. The construction is no more complicated than that of the single machine, yet the quantity of electricity is exactly doubled.

[The single electrical machine is exhibited ; the double electrical machine will, perhaps, be sent during the course of the Exhibition.]

The advantages of the machines constructed in this way, supported by experience of more than two years, may thus be briefly stated :—

(1.) The ebonite machines, constructed on the system of the exhibitor, with ebonites of a good quality (which may be easily had but must be carefully chosen) are at least as powerful in their action as the machines with glass discs, but they surpass them in being less costly, not liable to be broken, and much less dependent on the condition of the atmosphere. This must be appreciated in England, where, as is the case in Holland, glass electrical machines (working by induction) often remain inoperative owing to atmospheric moisture.

(2.) Although of very simple construction, they are very useful and powerful machines.

(3.) From a theoretical point of view they present many interesting properties when compared with machines in which glass is employed, and this led to the conclusion that they differ in their mode of producing electricity. An experimental investigation of this machine, stating its peculiarities, has been published in Poggendorff's Annalen, 1875, No. 10, pp. 278, 279.

1238. The First Instrument used to **Electrify** the Ink Bottle of the Syphon Recorder. *Sir W. Thomson.*

This was the first instrument used for producing the electricity required to electrify the ink bottle of the syphon recorder. What is now known as the mouse-mill, referred to in Clerk Maxwell's "Electricity and Magnetism," is a modification of this instrument, driven by intermittent electro-magnetic force. Described in Thomson's reprint of "Papers on Electro-statics and Magnetism," xxiii. 416–419.

1239. Modified form of **1238.** *Sir W. Thomson.*

1240. Further developed form of **1238.**
Sir W. Thomson.

One of the applications of this is to multiply indefinitely the electro-static indications obtainable from a feebly electrified body on the same principle as Nicholson's Revolving Doubler, and as the rotating induction instrument exhibited by Mr. C. F. Varley at the International Exhibition of 1861.

1241. Di-Electrical Machine. *M. Carré.*

1242. Holtz' Machine, with four plates. *M. Ruhmkorff.*

1242a. New form of Holtz' Machine.
Francis Pizzorno, Bologna, Italy.

1242b. Fixed Disc for a Holtz' Machine.
Augustus Righi, Professor of Natural Philosophy (Physics) of Bologna (Italy).

The greatest possible difference of potential between the conductors of a Holtz' machine depends on the difference of the potentials of the paper surfaces carried by the fixed disc. But this latter difference is limited by the discharges which continually occur along the fixed disc. I have joined perpendicularly on the fixed disc an ebonite plate, which separates it into two parts, so that the discharges must follow the two faces of the plate. The potentials of the paper surfaces are increased, and the sparks between the conductors become longer.

This machine possesses four rows of points, namely, the two rows of points of the conductors, and the two rows of points oblique communicating.

1243. Old Electrical Machine, with glass cylinders, one of which is covered with sealing wax, so as to obtain both positive and negative electricity.
Museum of King George III., King's College.

1244. Nairne's Early Electrical Machine, with glass globe. *Museum of King George III., King's College.*

1245. Cylinder Electrical Machine.
Museum of King George III., King's College.

1246. Plate Electrical Machine, with four rubbers.
Museum of King George III., King's College.

1247. Armstrong's Electric Boiler or **Hydro-Electric Machine.** *Museum of King George III., King's College.*

1248. Volta's Electric Lamp, or apparatus for lighting gas by means of an electric spark.
Museum of King George III., King's College, London.

It contains a leaden bottle for the generation of hydrogen gas. In the orifice are two wires separated from each other, which are connected to the two plates of an electrophorus. One of the wires is connected with the tap, so that the upper plate of the electrophorus is raised at the same time that the hydrogen is allowed to escape at the orifice, and the spark from the electrophorus sets fire to the hydrogen and thus lights the lamp.

1249. Induction Electric Machine. *T. Rob. Voss, Berlin.*

As there is no glass in Germany which insulates perfectly, Professor Helmholtz has used Leyden jars made of ebonite or vulcanite, which can keep electric charges for 14 days, and so 14 times longer than the glass jars of Kirchhoff.

1249a. Volta Faradaic Machine, with arrangement for taking in the pocket; also giving interrupted or continuous current, the batteries being of the constant Leclanché form.

Harvey, Reynolds, and Co.

1249b. Combined Holtz' and Bertch's Induction Machine, with arrangement for separating the same.

Harvey, Reynolds, and Co.

1249c. Induction Electric Machine. *J. Teller, München.*

1249d. Toepler's Induction Machine.

Royal Institution of Great Britain.

The apertures usual in the fixed disc are here dispensed with as unnecessary, the disc is thus rendered less breakable, and a greater action is obtained. The apparatus is very simple in construction and can easily be taken asunder for cleaning. The driving disc is at the same time utilised as the exciter of electricity.

1250. Holtz's Electric Machine, with fixed induction surface. *Borchardt, Hanover.*

1251. Holtz's Electric Machine, with movable induction surfaces. *Borchardt, Hanover.*

1252. Machine for **exciting Positive** and **Negative Electricity.** *E. Stöhrer, Leipzig.*

It has the form of a small disc electric machine. According as you take hold of the one or the other brass ball at the end of the caoutchouc frame you obtain a quantity of positive or negative electricity sufficient for various experiments with electro-dynamic and charging apparatus. The apparatus is also recommended for excitation of induction machines.

b. Galvanic Batteries.

1253. Water Battery.

Museum of Physical Apparatus, King's College.

1254. Daniell's Battery, employed in researches by Professor Daniell. *Museum of Physical Apparatus, King's College.*

1255. Early Voltaic Batteries:—

Babington's battery.
Cruikshank's ,,
Wollaston's ,,
Sturgeon's ,,

Museum of King George III., King's College, London.

1256. Hare's Calorimotor, or Deflagrator.

Museum of King George III., King's College, London.

1257. De La Rue's Powder Chloride of Silver Battery.

Tisley and Spiller.

1257a. Forty Cells of a Rod Chloride of Silver Battery, being part of a battery of 8,040 cells.

Warren De la Rue, F.R.S., and Hugo W. Muller, F.R.S.

The elements consist of a silvered flattened wire and a zinc (non-amalgamated) rod. The electrolytes are a solution of chloride of ammonium, 23 grammes to a litre of water, and fused chloride of silver cast on to the silver wire.

When the terminals are not connected the battery is quite inactive; one such battery has been in action since November 1874. In order to prevent contact between the chloride of silver and the zinc rod, the rod of chloride of silver is encased in a tube of vegetable parchment open at both ends. The cell is a glass tube closed with a paraffin stopper.

Such a battery will evolve three cubic centimetres of mixed gases, if connected up with a voltameter containing one volume of sulphuric acid, and eight volumes of water.

This battery is particularly well suited to experiments with a large number of elements, on account of its constancy.

1258. Portable Medical Battery, with modified form of De La Rue's chloride of silver and zinc elements.

Tisley and Spiller.

1259. New Galvanic Battery for Domestic Purposes.

Aurel de Ratti, Bradford Grammar School.

This Zinc-Carbon Battery is charged with a saturated solution of sulphate of magnesia or Epsom salts, a very cheap material. The flask above the cell is filled with crystals of this salt, on which a saturated solution of the same is poured until the flask is quite full. The cork with the glass tube is then forced down till the solution rises and fills the tube. A small cork is loosely fixed in the open end of the glass tube. No air must be allowed to remain in the tube or flask. The latter is now inverted, and the tube introduced through the round hole in the lid. The flask will be held in position by the projecting cork fitting into the round hole. The end of the glass tube will thus be immersed in the solution in the jar. The carbon-plate is finally pushed through the square aperture in the lid, and by a simple manipulation the cork is pushed from the open end of the glass tube.

1259a. Muirhead's new Manganese Battery.

Warden, Muirhead, and Clark.

1260. Gas Voltaic Battery devised by W. R. Grove, Esq., M.A., F.R.S., Professor of Experimental Philosophy in the London Institution (now Justice Sir W. R. Grove), and described by him in a communication read before the Royal Society, May 11th, 1843. Experiments with this battery are described in a postscript, dated July 7th (Phil. Trans., 1843, p. 91).

London Institution, Finsbury Circus, E.C.

It consists of a series of Woulfe's bottles, into the necks of which glass tubes closed at one end are fitted by grinding; each tube contains a slip of platinum foil, coated with finely divided platinum, the slip being connected with a wire sealed into the end of the tube, and which terminates outside in a little cup; the cups being filled with mercury, the tubes may be connected by wires dipping into the mercury. When the Woulfe's bottle and its tubes are

filled with dilute sulphuric acid, and one of the tubes is then charged with hydrogen and the other with oxygen, in quantities such as will allow the platinum to touch the acid, and the ends of a wire are dipped into the cups at the tops of the tubes, an electric current is produced. At the same time the gases in the tubes gradually diminish in volume, the volume of hydrogen which disappears being double that of the oxygen, and the current being generated, in fact, by the formation of water.

1261. Grove's Gas Battery, made by Spencer and Son, Dublin. *Prof. W. F. Barrett.*

The current in this battery is produced by the gradual union of the gases oxygen and hydrogen, which alternately fill the upright glass tubes. Strips of platinum passing down the tubes serve to make metallic connexion throughout the circuit.

1262. A Constant Gas Voltaic Battery devised by W. R. Grove, Esq., M.A., F.R.S., Professor of Experimental Philosophy in the London Institution (now Justice Sir W. R. Grove), and described by him in a communication to the Royal Society, dated May 30th, 1845. *London Institution, Finsbury Circus, E.C.*

To charge the apparatus, the stopper is removed from the end of the tube, and the glasses are filled to the top of the narrow platinum plates with acidulated water; acid is also poured into the end vessel, so as to cover the lump of zinc. The hydrogen which is evolved by the action of the zinc on the acid gradually expels the air from the main channel, and, when this is judged to be the case, the stopper is inserted; the hydrogen now will rapidly descend in all the tubes until the zinc is laid bare, and then remain stationary. A gas battery is now obtained, the terminal wires of which will give the usual voltaic effects, the atmospheric air supplying an inexhaustible source of oxygen, and the hydrogen being renewed as required by the liquid rising to touch the zinc; by supplying a fresh piece of zinc when necessary it thus becomes a self-charging battery, which will give a continuous current; no new plates are ever needed; the electrolyte is never saturated, and requires no renewal except the trifling loss from evaporation, which indeed is lessened, if the battery be in action, by the newly composed water.

1263. Element of M. Becquerel's Sulphate of Copper Battery. *Conservatoire des Arts et Métiers, Paris.*

1264. Twelve Elements of Galvanic Batteries on different systems, by Ruhmkorff. *Conservatoire des Arts et Métiers, Paris.*

1265. Pouillet's Thermo-Electric Battery.
Conservatoire des Arts et Métiers, Paris.

1266. Smee's Battery. Six cells, with arrangement for raising the plates out of the cells. *James How & Co.*

1266a. Set of Six Cell Smee's Batteries.
E. Cetti and Co.

1267. Winter's Machine, with 18-inch ebonite plate and condenser attached, for the accumulation of electricity.
Elliott Brothers.

1268. Replenisher. Designed by Sir W. Thomson for restoring electricity to the Leyden jar of his quadrant electrometer. *Elliott Brothers.*

A small charge being given to the Leyden jar, the replenisher increases or decreases the difference of potentials between the two coatings of the jar by a constant per-centage per half turn.

1269. Grove's Nitric Acid Battery. *Elliott Brothers.*

1270. Faure's Nitric Acid Battery. *Elliott Brothers.*

The advantages offered in this battery are, greater constancy, less inconvenience from fumes, the porous cell being a stoppered bottle, and the zincs used need not be amalgamated, common salt being used in the outer cell.

1271. Glass Battery Cell, with two carbon and two zinc plates. *Keiser and Schmidt, Berlin.*

1272. Glass Battery Cell, with two carbon and two zinc plates. *Keiser and Schmidt, Berlin.*

1273. Glass Battery Cell, with one carbon pole and one zinc plate. *Keiser and Schmidt, Berlin.*

1274. Dipping-Battery, with 10 elements, same construction. *Keiser and Schmidt, Berlin.*

1275. Dipping-Battery, with 16 elements, with pachydrope of the exhibitors' own construction. *Keiser and Schmidt, Berlin.*

1276. Battery for Field Telegraph Service, constructed for the Prussian Railway Battalion according to the plan of Captain Witte. *Keiser and Schmidt, Berlin.*

1277. Leclanché Cell, for working house telegraphs, modified by the makers. *Keiser and Schmidt, Berlin.*

1278. Drawing and **Description** of a **Galvanic Battery,** with arrangement for combining the elements ad libitum. *Dr. Tasché, Giessen.*

1279. Portable Battery for **Electro-therapeutic Purposes.** 24 elements. *Prof. Beetz, Munich.*

1279a. A Round Immersion Battery, with automatic break for medical purposes. *J. Teller, München.*

By this arrangement powerful action is obtained, and a very constant current, even with great resistance. The consumption of zinc is (in consequence of self-amalgamation in the acid chromate of mercury-oxide solution) very small, and this result is also favoured by the small immersion, which is limited by the slide on the upright bars. By the automatic interrupter, the battery can be used also with intermittent current, and such a battery current is to be preferred to the action of an induction current (because without alteration of poles).

1280. The Same, with **Ebonite Insulations** for the investigation of tension phenomena. 16 cells. *Prof. Beetz, Munich.*

1281. Delicate Battery, with four platinum-zinc elements, two silk conducting strings, with eight reserve plates in a case.
Kgl. Chirurgische Klinik, Breslau, Prof. Dr. Fischer.

1282. Delicate Battery, with four carbon-zinc elements.
Kgl. Chirurgische Klinik, Breslau, Prof. Dr. Fischer.

1283. Delicate Battery, with two carbon-zinc elements, two conducting strings, and three reserve plates in case.
Kgl. Chirurgische Klinik, Breslau, Prof. Dr. Fischer.

1284. Small Battery, with two platinum-zinc elements.
Kgl. Chirurgische Klinik, Breslau, Prof. Dr. Fischer.

In galvanocaustics (the art of destroying diseased portions of tissue by means of the electric current) the batteries used generally consist of four very large Grove or Bunsen elements. Wires proceed from the battery to a piece of platinum, which is to be raised to a red heat. This collection shows Middeldorpp's original arrangement, as used in Breslau, and also recent modifications.

c. Thermo-electric Batteries.

1285. Thermo-electrical Battery, bismuth and antimony.
Geneva Association for Constructing Scientific Instruments.

1285a. Apparatus for Volta's Fundamental Experiment, with arrangement for chloride of calcium, with two brass, one copper, and one zinc plate, with insulating handle.
Warmbrunn, Quilitz, & Co., Berlin.

1286. Nobili's Thermo-Electric Pile, of 54 pairs of bismuth and antimony bars, soldered alternately together; the smallest temperature between the two faces of the pile developes a current, readily indicated by a suitable galvanometer. *Elliott Brothers.*

1287. Noë's Thermo-electric Battery of 96 pairs. Convenient for lecture experiments. *George Gore, F.R.S.*

Attains its maximum power in about one minute. May be heated to low redness. Decomposes water freely. Will excite an electro-magnet to sustain 2 cwt. It has an arrangement, or "current transformer," by means of which its entire power can be employed with three different combinations of its elements, viz., as 96 by 1, 48 by 2, or 24 by 4, and changed instantly from one combination to another. The connexions of the "transformer" require no cleaning. Made by W. J. Hauck, Vienna.

1288. Small Single-cell Apparatus, with platinum-plates, for showing the thermo-electric properties of liquids.
George Gore, F.R.S.

(*See* Philosophical Magazine, Jan. 1857.)

1289. Single-cell Apparatus, for examining the thermo-electric properties of liquids. *George Gore, F.R.S.*

(*See* Proceedings of the Royal Society, 1871.)

1290. Large Single-cell Apparatus, with platinum-plates, for showing the thermo-electric properties of liquids.

George Gore, F.R.S.

1291. Four-cell Apparatus, with copper plates, for showing the thermo-electric properties of liquids. *George Gore, F.R.S.*

(*See* Philosophical Magazine, 1857.)

1292. Twelve-cell Apparatus, with platinum-wire electrodes, for examining the thermo-electric properties of liquids.

George Gore, F.R.S.

(*See* Proceedings of the Royal Society, 1871.)

1293. Model of the most improved form of apparatus for investigating the thermo-electric properties of liquids. Used with ribbons of platinum, gold, palladium, and silver.

George Gore, F.R.S.

1294. Thermo-Electric Battery or Clamond Pile.

Thermo-Electric Company.

The poles or generators are constructed of zinc and antimony, both being metals bearing great electrical properties. The electricity is given out without any intermediate agency, except heat, which is generated as gas; coke or charcoal is consumed. Economy in maintenance, and cleanliness in application, gives this arrangement an advantage over other batteries, and the current obtained is constant and free from polarization or exhaustion.

1297. Thermo-Battery. *Siemens and Halske, Berlin.*

1297a. Thermo-Electric Pile, small student's form, nickel-plated. *Harvey, Reynolds, and Co.*

1298. Thermo-electric Pile (Noë's arrangement).

P. Dörffel, Berlin.

The elements, consisting of a round rod (positive) and thin wires (negative), are arranged in two opposite rows of 64 elements each, whose heating bars (cast of positive metal and protected against the flame by copper casing) project in a row into the open space between the elements, so that they are all alike heated by the stand of Bunsen burners below, and convey the currents to the elements. The cooling of the other junctions is effected by means of metallic cool-plates attached to them, supported by the wooden frame under the elements. The electro-motive force is equal to 6 Bunsen or 120 Jacobi-Siemens units. The resistance = 2·45 Siemens units.

1298a. Nobili's First Thermo-Electric Battery.

Prof. Dove, Berlin.

1298b. Melloni's First Thermo-Electric Pile.

Prof. Dove, Berlin.

1298c. Antinori's First Apparatus for Induction for Induction Sparks. *Prof. Dove, Berlin.*

1299. Thermo-pile (Noë's system), with 20 elements in radiating arrangement, heated by gas. The electro-motive power is equal to five Bunsen elements. *P. Dörffel, Berlin.*

Here the elements are arranged radially, so that the heating bars all run to a middle point, where they can be heated by the single flame of a Bunsen burner. The cooling is done with metal plates which are rolled into a tubular form, and serve at the same time as stands for the battery. The electro-motive force is equal to 1 Bunsen or 20 Jacobi-Siemens units. This apparatus (as also the next, 1300) is recommended for small experiments in electrolysis, &c.

1300. Thermo-electric Pile (Noë's system), heated by a spirit lamp, with 20 smaller elements, and consequently of greater resistance. The electro-motive power is equal to one Bunsen element. *P. Dörffel, Berlin.*

1301. Thermo-electric Pile (Noë's system), heated by a spirit lamp, with 10 smaller elements. Its electro-motive power is equal to 0·5 Bunsen element. *P. Dörffel, Berlin.*

Designed specially for medical use, in connexion with a small induction apparatus. Should long action be desired it is well to place the battery with lamp in a vessel with water, to avoid the great heating its small size involves, and to exalt the action.

1301a. Thermo-Electric Generator (Clamond's Patent). Constructed either for electrotyping, plating, gilding, or telegraphy. A pile of 100 bars burning 4 feet per hour, will deposit an ounce of copper per hour.

Thermo-Electric Generator Company (Clamond's Patent).

The Thermo-Electric Piles or Generators are constructed of elements, one pole of which is tinned iron, the other being an alloy of two parts of antimony to one of zinc. The iron is cast into the alloy, and thus a perfect connexion is made. The pairs thus formed are then laid side by side, and being cemented together, form a ring or crown (the cement used is a mixture of asbestos and silicate of soda) ; one crown being complete another is laid above it, though insulated from it by the same cement, and so on, giving the pile a cylindrical form. The junctions are heated thus : Up the centre of the pile is placed a perforated earthen tube and gas issuing from a Bunsen's jet burns at the perforations, heating an iron core red hot, which radiates its heat to the junctions of the pairs, thus the flame never impinges on the metals, and all oxidization, &c. is obviated; the heated air passes over the top of the iron core, and curling down, escapes by a pipe from the bottom of the pile. The elements of each crown are connected in series, but the terminals of every crown are brought into a wooden support and can be connected at will for high tension or great quantity. As a standard of power the following may be used : —

A 100 bar pile consuming 4 feet of gas per hour has E.M.F. 5 volts., Int. Res. 1 ohm.

A 240 small tension bar pile, consuming 4 feet of gas per hour has E.M.F. 12 volts., Int. Res. 6 ohm.

Piles are also made to be heated by coke or charcoal, and a battery having an E.M.F. of 20 volts, and Int. Res. of 4 ohms burns 2 lbs. of coke per hour. Petroleum is also used for heating the piles.

1301b. Thermo-Electric Pile of Hydrogenium.
Prof. Dewar.

Consists of alternate layers of Palladium and Hydrogenium; electromotive force equal to that of iron and copper.

d. Induction Coils.

1302. A **Small Ruhmkorff's Induction Coil.**
Rob. Voss, Berlin.

1303. Ruhmkorff's Coil. *Frederick Guthrie, F.R.S.*

The current from a galvanic battery passing down a spiral of copper wire excites a magnet, which by its attraction so moves a steel spring as to interrupt the current. The current being thus broken, the magnetism ceases and the current is restored. The result is a very rapid making and breaking of the current in the spiral or primary. Inside the primary are bars of soft iron; outside, many miles of fine insulated copper wire called the secondary. Connected with the primary by wires, one on each side of the make and break, is a tin-foil condenser. This absorbs the extra-current when the primary is broken, and acts to augment the secondary when the primary is made. The interior magnetism acts in the same direction.

1303a. First Induction Machine, called **"de Pixii,"** constructed under the direction of Ampère.
College of France, Paris.

1304. Six-inch Induction Coil, and Browning's Spark Condenser, for obtaining spectra of metals by the induction spark. *John Browning.*

When using the spark condenser the amount of coated surface introduced may be varied at pleasure, and the density of the spark thus regulated.

1304a. Apps' Patent Induction Coil, giving sparks of 17 in. in air, with a battery of five Grove's cells, platinum, 5 × 3 in. immersed. *Alfred Apps.*

1304b. Henry's Induction Coils.
Museum of King George III., King's College, London.

1305. Large Induction Coil, with Foucault's break; will give 18-inch sparks. A cube of glass was pierced by this coil.
M. Ruhmkorff.

1305a. Electric Necessaire, containing Ruhmkorff bobbins.
M. Loiseau, jun., Paris.

1306. Induction Apparatus for medical purposes.
Keiser and Schmidt, Berlin.

1307. Induction Apparatus for medical purposes.
Keiser and Schmidt, Berlin.

1308. Induction Apparatus for medical use.
Keiser and Schmidt, Berlin.

1309. Spark Induction Machine, No. 1, with armature and Geissler's tubes. *Keiser and Schmidt, Berlin.*

1310. Spark Induction Machine, No. 2, with armature and Geissler's tubes. *Keiser and Schmidt, Berlin.*

1311. Spark Induction Machine, length of spark, six millimeters. *Keiser and Schmidt, Berlin.*

1312. Spark Induction Apparatus, length of spark, one centimeter. *Keiser and Schmidt, Berlin.*

1313. Induction Apparatus, length of spark, 4·5 centimeters. *Keiser and Schmidt, Berlin.*

1314. Induction Apparatus, length of spark, 8 centimeters *Keiser and Schmidt, Berlin.*

1315. Magnetic-induction Machine.
Baur and Haebe, Stuttgart.

1. This apparatus, containing several electro-magnets and a current regulator, is furnished with double coils of wire, and may be used to set in action electric apparatus of very various resistance and with very quick interruption of current, *e.g.*, Ruhmkorff coils. In general, any experiments may be made with it that are made with batteries of 1–6 Bunsen elements. It is suitable, for medical purposes, galvanocaustics, &c., and, if a part of the rotating electro-magnets be wound with fine wire, for production of a constant current up to 60 Meidinger elements.

e. Magneto-electric Machines.

1316. Ladd's Dynamo-Magneto-Electric Machine, with two wires on one armature. *William Ladd & Co.*

Invented March 1867. (*See* Proceedings of the Royal Society, No. 91, 1867.)

This was the first machine with two armatures, one being employed to excite the electro-magnets and the other to produce an electric current, which may be used for any purpose to which a battery is applicable.

1316a. Ladd's Dynamo-Magneto-Electric Machine, with two wires on one armature. This machine will heat 15 inches of platinum wire. *William Ladd & Co.*

1317. The first Magneto-Electric Machine, with circular magnets, 1866. *William Ladd & Co.*

1318. Magneto-Electric Machine, with circular magnets, larger form, 1867. *William Ladd & Co.*

1319. Magneto-Electric Machine (direct current).
James How & Co.

1320. Magneto-Electric Machine (Duchenne's form).
James How & Co.

1321. Magneto-Electric Machine (Clark's form). An early machine by Logemann, of Haarlem. *James How & Co.*

1322. Electro-Magnetic Coil Machine, for medical application. Primary and secondary currents. *James How & Co.*

1323. Magneto-Electric Machine, with alternate current for production of light. *La Société l'Alliance.*

An electro-magnetic machine, with four discs or 64 bobbins with alternate current for the production of light. This machine, which requires a three horse power, revolves from 400–450 lines per minute and produces 200.

1324. Magneto-Electric Machine, workable by hand or steam. *La Société l'Alliance.*

An electro-magnetic machine for the purpose of demonstration with eight bobbins with direct and alternate current, workable by hand or steam.

1325. Experimental Magneto-Electric Machine, the first constructed in which electricity and magnetism, rendered active by the expenditure of mechanical force, were made to act and re-act on one another in such a way as to greatly increase the development of their force. *S. Alfred Varley.*

This machine was the first of its class, and acted on what was a new principle at the date of its construction. The new principle consisted in making electricity and magnetism, rendered active by the expenditure of mechanical force, act and re-act on one another in such a way as to greatly increase the development of their forces. In this machine iron bobbins wrapped with insulated wire are revolved between the holes of very feeble magnets made of soft iron. The electricity (small in amount when the machine is first put in motion) which is developed in the insulated wire of the bobbins passes, by means of a commutator, through convolutions of insulated wire surrounding the soft iron magnets, and renders them more highly magnetic.

The magnetism of the soft iron magnets being thus increased, developes a corresponding increased quantity of electricity in the revolving bobbins, which re-acts on the soft iron magnets, rendering them still more highly magnetic.

The expenditure of mechanical force giving motion to the machine is greater as the magnetism and electricity developed increases the consumption of mechanical force having relation to the quantity of electricity rendered active.

1326. Gramme's Magneto-Electric Machine, for electrotyping. *H. Fontaine.*

1327. Gramme's Magneto-Electric Machine, for electric light. *H. Fontaine.*

1328. Gramme's Magneto-Electric Machine, for electric light of great power. *H. Fontaine.*

1329. Gramme's Magneto-Electric Machine, for demonstrating. *H. Fontaine.*

1330. M. Le Roux's Electro-Magnetic Apparatus, for showing the effect of magnetism on copper discs. *M. Ruhmkorff.*

1331. Model of a Magneto-Electric Machine, designed to illustrate the advantage gained by the use of an electro-magnet in place of the usual permanent magnet. *William Raynor.*

This model of a magneto-electric machine is one that has been constructed for the purpose of showing the great increase of the electric current by the use of an electro-magnet in place of the permanent magnet, when such magnet is excited or charged by a galvanic cell; and this principle is applicable to all magneto-electric machines using soft iron magnets.

1332a. Portable Magneto–Electric Machine, with double coiled magnet. *Harvey, Reynolds, and Co.*

1336. Electro-Dynamic Light-producing Machines. *Siemens and Halske, Berlin.*

For setting these dynamo-electric machines in action a force of 6 horse-power is required for the larger and one of 3 for the smaller.

1336a. Various examples of Magneto-Electric Apparatus.

Electro-magnet, by Repmann.
Electro-magnet, by Jablokoff.
Electro-magnetic machine by Gramme, with a Jamin magnet of 0·08m.
Two secondary elements, by Planté.
Battery of 20 secondary elements, by Planté.
Battery of 20 secondary elements, by Planté.
Regulator of electric light, by Serrin, with glass globe.
Magneto-electric machine, by Gramme, for electric light of 150 burners.
Magneto-electric machine, by Gramme, with electro-magnet for laboratory.
Magneto-electric machine, by Gramme, with a Jamin magnet (small model).
Magneto-electric machine, by Gramme, with a Jamin magnet (large model with flier and pedal).
Exploder, with Jamin magnet (large model) with bobbin, cable, and key.
Exploder, with Jamin magnet (medium model).
Magnet, Jamin's, with plates 0·05m. in width.

M. Bréguet, Paris.

f. Other Modes of Producing Electricity or Electric Currents.

1337. Apparatus, designed to obtain electric currents by means of the combined action of gravity and motion. Preliminary experiments only have yet been made with it. *George Gore, F.R.S.*

1338. Apparatus for investigating electric currents produced by the friction of different metals. (Not yet completed.) *George Gore, F.R.S.*

1341. Delezenne's Circle. An instrument for developing electrical currents by the agency of terrestrial magnetism.

Elliott Brothers.

1342. Apparatus by which **Forbes** procured an **Induction Spark** from a **Natural Magnet.** *Trans. R. S. Edin.*, 1833.

University of Edinburgh.

II.—APPARATUS FOR REGULATING THE PLACE AND TIME AT WHICH THE EFFECTS OF AN ELECTRIC DISCHARGE OR CONTINUOUS ELECTRIC CURRENT ARE PRODUCED.

1343. Six Specimens of Tubular Binding Screws for making electrical connexions. *George Gore, F.R.S.*

1343a. Specimens of Wire for Electric Apparatus.

1. Copper wires, covered with gutta-percha (1, 2, 25).
2. Copper wires, covered with gutta-percha and cotton (3).
3. Copper wires, covered with cotton (4, 5, 6, 9, 11, 12, 13, 14, 26).
4. Copper wires, covered with silk (7, 8, 10, 15 to 23, 27).
5. Elastic poires, with their cordons (24).
6. Wires covered with various metals, with statement of their resisting power. *Madame Bonis, Paris.*

1344. Double Terminal, by Captain R. G. Scott, R.E., to show the direction in which the spark tends to travel.

School of Military Engineering, Chatham.

1345. Single Plug Key, to close or break contact for long or short durations. *Elliott Brothers.*

1346. Fall-hammer, to obtain perfect equable closing of a circuit.

Prof. Engelmann, Physiological Laboratory and Ophthalmological School, Utrecht.

On a brass prismatic lever, movable round a horizontal axis, slides the bridge, a copper cover having underneath two amalgamated copper points. On depressing a spring the lever falls from a nearly vertical position, and plunges the bridge into two mercury vessels, movable on a horizontal sledge, and connected with the battery. A spring prevents the bridge from rebounding. Velocity of fall to be regulated by moving the bridge on the lever with corresponding displacement of the mercury vessels on the horizontal sledge.

By using the bridge as branch-closing, equable breaking (more correct diminishing) of a current may be obtained. The bridge being in the primary circuit of an induction apparatus, the breaking is every time to be effected at another place of the circuit, before lifting the bridge from the mercury, in order to prevent oxidation of the mercury by the spark.

The instrument can easily be managed with one hand.

1347. Firing Key, for torpedoes, &c. A simple contact key, with a movable piece of vulcanite, which can be brought between the two platinum contacts to prevent fatal results by accidentally closing the circuit. *Elliott Brothers.*

1348. Apparatus for reversing the direction of an Electric Current. Used with an electro-magnetic torsion apparatus. *George Gore, F.R.S.*

(*See* Philosophical Transactions of the Royal Society, Vol. 164, p. 529.)

1348a. A Current-reversing Electrode, with adjoints. *J. Teller, München.*

This gives a more convenient change of current than the commutators so far as electro-medical apparatus is concerned.

1349. Double Reversing Key, used for cable testing. *Elliott Brothers.*

1350. Thomson's Reversing Key, used in connexion with the electrometer, for facilitating the measurement of the electrostatic capacity of a cable or condenser. *Elliott Brothers.*

1351. Lambert's Key, constructed for charging or discharging cables and condensers. *Elliott Brothers.*

1352. Spottiswoode's Rapid Break, for use with Intensity Coils. *Tisley and Spiller.*

By means of this break the discharge in vacuum tubes can be regulated, and the motion of the stratifications diminished or rendered stationary, as required.

1353. Contact Repeater, by Captain Armstrong, R.E., to repeat electric contacts of exactly similar duration. *School of Military Engineering, Chatham.*

1354. Forms of discharge on making and closing an induction current. *Prof. Donders, Utrecht.*

The trial with the noematachograph to have the instant of stimulation registered on the chronoscopic line by the current itself, led to the discovery :

1. That the discharge can form a long series of sparks.
2. That the electricity disappears more slowly when the spring rests on metal, more rapidly when it rests on a plate of mica, than in the form of sparks making holes in the paper. (Compare Onderzoekingen gedaan in het phys. labor. Ser. 2, T. III. 1870; and Wiedemann, Die Lehre vom Galvanismus und Electromagnetismus, 2e Auflage, 1874, B. II., s. 360.)

1355. Drawings showing the patent system of lightning conductors applied to buildings. *J. W. Gray & Son.*

1356. Model of mid-section of a Ship, showing the patent system of lightning conductors applied to vessels in Her Majesty's service, &c. *J. W. Gray & Son.*

1357. Indestructible Solid Copper Tape Lightning Conductors. Small and large sizes. *Sanderson & Proctor.*

This form of lightning conductor possesses the greatest conducting surface. Hitherto it has been made in short lengths riveted together; now it is made in any length without joints, thereby offering no resistance to the free passage of the electric fluid.

1358. Copper Rope Lightning Conductors, improved. The smallest and largest sizes. *Sanderson & Proctor.*

1359. New Lightning Conductor Apparatus.
Professor Carl Wenzel Zenger, Prague.

This apparatus consists of lightning conductors arranged symmetrically, balls being used instead of conical points. A plan shows its application to the I. R. Real School, and to the National Theatre at Prague.

1360. Top of Lightning Conductor. The lower part is made of gun metal, the upper of copper, and the extreme point of gold or silver. Constructed according to the instructions of Professor Ed. Hagenbach-Bischoff, in Basle. *G. Linder, Basle.*

The electricity escapes easily through good conductors from points and edges; the point does not oxidize in the atmosphere, and being a good conductor is not liable to be melted by electricity.

1361. Needle of Lightning Conductor, brass gilt.
Geneva Association for Constructing Scientific Instruments.

1362. Lightning Conductors (various kinds).
John Faulkner, Manchester.

Two photographs of expedients for applying lightning conductors to high spires and factory chimneys, and for the repair of high spires and chimneys.

1363. Models of Lightning-Conductors of the latest construction. *Mittelstrass Brothers, Magdeburg.*

1364. Apparatus serving **for the separation and collection of induced currents,** constructed by Dr. Th. Tasché, manufactured by Staudinger & Co., in Giessen.
Dr. Tasché, Giessen.

1364a. Current Analyser, with glass axis, made by Jung, of Giessen. *Physical Institute (Univ. of Giessen), Dr. Buff.*

The "current analyser" could be occasionally used for experimental research in voltaic induction, to separate the two induced currents, and to study the proportion of their intensities or electro-motive forces. *See* Poggendorff's Annalen, Vol. 127, p. 57.

1365. Binding Screws for **Galvanic Work.**
M. Th. Edelmann, Munich.

1366. Current-key for **Beetz's Compensation Method.**
M. Th. Edelmann, Munich.

III.—APPARATUS FOR ACCUMULATING ELECTRICITY.

1367. Leyden Jar of five and a half square feet coated surface. *Teyler Foundation, Haarlem.*

This jar is one of the 100 jars arranged in four cases, by which Van Marum constructed a battery of 550 square feet coated surface. The coatings of tinfoil have been renewed recently; but all is restored in the form in which it was used by Van Marum.

See Van Marum, "Machine Électrique," II., p. 195.

1368. Leyden Battery of 15 jars.
Teyler Foundation, Haarlem.

This battery is one of 16 used by Van Marum for his famous experiments, giving a total coated surface of 225 square feet.

The coatings of tinfoil have been renewed recently; the bottom of tea-lead in the case is also restored; and the outer coating of the case bottom, which Van Marum also made of tea-lead, has been replaced by zinc.

See Van Marum "Machine Électrique," I. p. 155, and II. p. 3.

1369. A Battery of 10 one-gallon Leyden Jars.
Frederick Guthrie, F.R.S.

This battery stands in a mahogany frame. The jars stand upon perforated zinc. There is an arrangement for drying them by a current of hot air. The spark from this battery deflagrates a platinum wire a foot long.

1369a. A series of Leyden Jars, with connectors, hard cement. Cover 10 pieces from 90 to 100mm. high.
Warmbrunn, Quilitz, & Co., Berlin.

1369b. Battery of Leyden Jars, consisting of six jars 312mm. high, in mahogany case. *Warmbrunn, Quilitz, & Co., Berlin.*

1369c. A Cylinder, on insulating support.
Warmbrunn, Quilitz, & Co., Berlin.

1369d. A Cylinder, with elder-pith balls.
Warmbrunn, Quilitz, & Co., Berlin.

1369e. Sphere, on insulating support, with two movable hemispheres on shellac rods. *Warmbrunn, Quilitz, & Co., Berlin.*

1369f. Large dissected Leyden Jar.
Warmbrunn, Quilitz, & Co., Berlin.

1370. Spiral Leyden Jar. *Frederick Guthrie, F.R.S.*

Two sheets of ebonite, alternating with two sheets of tinfoil, are rolled up together. The central knob is connected with the inner edge of the arc of the foils; the brass girdle is connected with the other sheet. A Leyden jar is thus formed which is compact with a large surface.

1371. Mica-plates for isolating electrical apparatus.
Max. Raphael, Breslau.

Mica can be rendered electrical by the least friction, hence its frequent employment as an excellent isolating material, especially on account of the facility with which it can be worked.

1372. Two Large Condensers, consisting of Leyden jars, each 400 millimeters high and 200 millimeters in diameter, which serve as well for one machine as the other. *Borchardt, Hanover.*

1372a. Adjustable Disc Condenser, which has also been used as a spark micrometer. *Sir William Thomson.*

It was in this instrument that the sound produced in an air condenser by a sudden change of potential was first heard. The lower part of the cell is arranged to hold cups of pumice-stone impregnated with sulphuric acid.

1372b. Cylindrical Condenser, for measuring capacity in absolute electrostatic units, described in Messrs. Gibson and Barclay's paper in the Transactions of the Royal Society for 1871. *Sir William Thomson.*

1372c. Condenser for the Holtz Bertsch Electrical Machine. *Messrs. Mottershead & Co., Manchester.*

IV.—APPARATUS FOR PRODUCING AND OBSERVING EFFECTS OF ACCUMULATED ELECTRICITY.

1373. Apparatus for demonstrating the fundamental laws of electrical and magnetical attraction and repulsion, made according to the instructions of Professor Ed. Hagenbach-Bischoff, in Basle. *G. Linder, Basle.*

The ebonite rods are negatively electrified when rubbed with fur, and positively electrified when rubbed with gun cotton. (*See* Carl, Repertorium der Experimental Physik, VIII., p. 75.)

1374. Insulated Pith-Ball Stand, with mahogany arm; the arm is itself a box in which the pith balls may be placed when it is not in use. *Museum of King George III., King's College.*

1648. Series of Elder Pith Balls. *Warmbrunn, Quilitz, and Co., Berlin.*

V.—APPARATUS FOR PRODUCING AND OBSERVING EFFECTS OF THE DISCHARGE OF ACCUMULATED ELECTRICITY, WITH SPECIMENS OF PERMANENT RESULTS PRODUCED.

1375. Photographs of **Sparks** from a **Holtz Machine,** in cold and in heated air. (See Trans. R. S. Edin., 1874–5.) Taken by an instantaneous process, a quartz lens being employed. *Professor Tait, Edinburgh.*

1375a. Air Thermometer after Riest.

Warmbrunn, Quilitz, & Co., Berlin.

1375b. Spark Micrometer after Riest.

Warmbrunn, Quilitz, & Co., Berlin.

1376. Apparatus used by M. Rijke to measure the distances at which the Leyden jar explodes.

Professor Dr. P. L. Rijke, Leyden.

1377. Vacuum Tube for electric discharge. 1856.

Teyler Foundation, Haarlem.

Masson in Paris used a Torricellian vacuum sealed by the lamp, in his extensive researches on the electric spectrum. Some time afterward, Mr. Geissler, in Amsterdam, made this Torricellian vacuum at the instigation of Prof. Van der Willigen, now director of the Teyler Museum, whose property it is at present. The experiments with this tube are described in Poggendorff's Annalen, vol. xcviii. p. 487, 1856. Subsequently Mr. Geissler in Bonn constructed his various well-known and beautiful tubes. This tube contains a little mercury and carbonic oxide gas.

1377a. Four Geissler's Vacuum Tubes. *E. Cetti and Co.*

1377b. Collection of Geissler's Tubes.

Dr. H. Geissler, Bonn.

1377c. 1. **Apparatus** for the **Production** of **Hydrogen Gas.**

2. Tube, by Geissler, for two gases.
3. Tube, by Geissler, forming a diadem.
4. Tube, by Geissler, forming a diadem.
5. Tube, by Geissler, with inner spiral.
6. Tube, for liquids, with six spirals.
7. Phosphorescent tubes, set in the form of writing. These tubes preserve their brilliancy in the darkness long after being exposed to solar light.

Alvergniat Frères, Paris.

1377d. Three Vacuum Tubes, to show the connexion between the resistance of rarefied air and the phenomenon at the cathode, the so-called negative glow. *Prof. Hittorf, Münster.*

Apparatus (A) made by Dr. Geissler, of Bonn, consists of two balls which communicate together by two tubes of equal width, one short and one of spiral form $3\frac{3}{4}$ mètres long. The electrodes of aluminium wire pass through the balls and end in the short tube so that there is a free interval of only 2 mm. between them. The opening current of the Rhumkorff coil passes, in consequence of the great rarefaction of the air in the tube, not by this short path, but prefers the longer one. If the latter, by closure of the glass cock, be stopped, the passage is effected, but only with much greater tension, by the short interval. The tube (B) has the same arrangement, but without the glass cock. It is used in place of (A) where the air is able to penetrate and the required vacuum ceases. The glass vessel (C) consists of a wide reservoir

and a cylindrical tube, each of which holds one of the two equally long wires as electrodes. The tension of electricity with which passage occurs is much greater when the wire serves as cathode in the narrow part than when it is anode. This may be shown if a spark micrometer be introduced in the induction current near the tube, and for each of the two directions the interval of the balls be determined with which the current takes the path through the tube. If the wire in the wide reservoir, being cathode, be placed in conductive connexion with the third aluminium wire, which is in the beginning of the cylindrical tube, the current can no longer pass over in the latter to the former. This, therefore, loses its negative light, and only with the greater tension, such as occurs with the other direction, is the passage of electricity effected. (Cf. Pogg. Ann., Bd. 136, p. 197.)

The aluminium wire, which is quite sheathed with glass, with exception of the last cross section, is taken as cathode of the opening induction-current. The straight discharge from the cross section, when the tubes are brought over and between the poles of an electro-magnet, behaves like a flexible conductor which is fixed at one end and at the other freely movable, and follows the Laplace-Birl laws. (Cf. Pogg. Ann., B. 136, p. 213.)

1377e. Three Tubes of Glass, with rarefied air to show the magnetic behaviour of the negative glow light.

Prof. Hittorf, Münster.

5. The negative electric discharge which, with great rarefaction, occurs at a cathode with small surface, raises the conducting particles of gas to a very high temperature. When strong induction currents are used, these, notwithstanding their small mass, are capable of raising the surface of badly-conducting solid bodies with which they come into contact to a red heat. This heating, which the negative discharge gives in much greater degree than the positive, produces with the best light-givers, like sulphide of calcium, a light of dazzling intensity.

1377f. Three Glass Tubes of Rarefied Air and Sulphide of Calcium, to show the phosphorescence of the negative electric light. *Prof. Hittorf, Münster.*

1378. Gassiot's Star. *Frederick Guthrie, F.R.S.*

This exhibits (1) the varieties of the electric discharge through various rarefied gases in tubes of different shapes, and (2) by being rotated shows by the retention of images the intermittent nature of the discharge.

1379. Block Specimen of Glass, 2½ inches high, penetrated vertically by an electric discharge. (By Ruhmkorff, of Paris.)

George Gore, F.R.S.

1380. Effect of Lightning. Portion of a half-sovereign and a fragment of sheet iron fused together by a discharge of lightning in the colony of Natal. This and other coins were in a tin box, of which this fragment alone remained.

Robert James Mann, M.D.

1381. Metals fused into Glass by Lightning.

Alfred B. Harding.

Frame No. 1 consists of strips of zinc, tin, and lead, fused into glass by an actual flash of lightning, collected by means of "exploring wires" stretched

over the grounds of the late Andrew Crosse, and converged into his electrical room, as shown in the stereograph. It was here accumulated in the great Leyden battery of 50 jars, and passed thence by dischargers through the metals, which were burnt into the glass on which the strips were laid.

Frame No. 2 contains composite strips of copper and iron, gold and tin, and gold, silver, and copper, fused in like manner.

A photograph of the Leyden battery, with which the experiments were performed, accompanies the frames.

1382. "Thunder House," or model to illustrate the identity of lightning and electricity, and the use of lightning conductors in protecting buildings—said to be the first model of the kind, and to have been made by Dr. PRIESTLEY with his own hands.

Conrad Wm. Cooke, M. Inst. C.E.

1383. Old Electric Egg (beginning of last century).

Prince Plesh.

The great age of the instrument appears both from tradition and from the style of the wooden frame and the nature of the brass work. It is certainly one of the oldest instruments of the kind.

1384. Apparatus employed by Sir Charles Wheatstone to determine the **Velocity** and **Duration** of the **Electric Discharge.**

Rotating mirror. Spark disc. Early rotating disc with balls and sliding rod.

Museum of Natural Philosophy, King's College.

791. Rotating Tube Holder, a contrivance for containing a number of Plücker's tubes, and obtaining their spectra successively without loss of time. *John Browning.*

792. Rotating Metal Holder, suggested by Mr. Lockyer, for holding specimens of all the principal metals, and obtaining their spectra successively, or for the purposes of comparison.

John Browning.

1385. Riess' Spark Micrometer. *F. Rob. Voss, Berlin.*

This is well suited for school use, as it is not very dear, and its action is, in proportion, as good as that of larger machines.

There are new arrangements in the Leyden jar for raising or turning the needle without shaking the entire instrument (a thing to be avoided).

1386. Apparatus for testing with Lightning Conductors. *M. Th. Edelmann, Munich.*

1387. Electrograph, apparatus for the production of electric sand-figures, constructed, from the plan of the exhibitor, by M. Th. Edelmann. *Prof. W. von Bezold, Munich.*

This serves for study of the nature of the electric discharge in simple or branched circuits, with the aid of sand figures. The figures exhibited have partly been produced with this apparatus, partly under the air pump, and by means of a caoutchouc solution transferred from the ebonite plate to black

silk-paper. They are accordingly not copies, but true originals, produced by the discharge.

1388. Framed Table, with electric dust figures.
Prof. W. von Bezold, Munich.

VI.—APPARATUS FOR PRODUCING AND OBSERVING EFFECTS OF CONTINUOUS ELECTRIC CURRENTS.

a. HEATING AND LUMINOUS EFFECTS.

1389. Diagram showing the **Amounts** of the **Electro-motive Force,** and the **Peltier** and **Thomson Effects** in a **Thermo-electric Circuit** of **Iron-Copper,** both junctions being at temperatures under the neutral point. For teaching purposes.
Professor Tait, Edinburgh.

1390. Peltier's Apparatus, for studying the effect of heat in metals subjected to the action of electricity.
Conservatoire des Arts et Métiers, Paris.

b. CHEMICAL EFFECTS.

1391. Apparatus for the polar **Decomposition** of **Water** by means of atmospheric electricity or the currents of the ordinary electrical machine. The gases are collected in fine thermometer tubes, by which means their absorption by the electrolyte is avoided.
Dr. Andrews, F.R.S.

1391a. Apparatus for Decomposition of Water, peculiar construction, with graduated tubes for the separated gases and for the detonating gas. *Warmbrunn, Quilitz, & Co., Berlin.*

1392. Bottle, containing fragments of pure **Electro-deposited Metallic Antimony.** *George Gore, F.R.S.*

(*See* Philosophical Transactions of the Royal Society, 1857, 1858, and 1862.)

1393. Two Specimens of Electro-deposited Antimony; one of the explosive, and one of the pure variety.
George Gore, F.R.S.

1394. A Rare Specimen of pure Carbon, deposited by means of an electric current upon a rod of platinum.
George Gore, F.R.S.

c. ELECTRIC DIFFUSION AND CHANGE OF SURFACE-TENSION.

1395. Apparatus for producing Vibrations and Sounds, and an intermittent electric current by means of the electrolysis of

a solution of cyanide of potassium and mercury with electrodes of mercury. *George Gore, F.R.S.*

The effects are produced by the alternate rapid formation and destruction of films upon the positive electrodes. (*See* Proceedings of the Royal Society, Vol. 12, p. 217.)

1395a. Electro Capillary Force Machine, after Lippmann.
R. Jung, Heidelberg.

To set this machine in action, the two wide glass vessels are first filled to a height of 1 to 3 cm. with mercury, placed in position in the glass trough, and then filled two thirds with pure dilute sulphuric acid. Then the two bundles of thin glass tubes are pushed repeatedly down into the mercury, so that the air is driven out, and the tubes and their intervals are quite filled with mercury and acid. Then the bundles are fixed by screwing to their frames, so as to be about half immersed in the mercury, and to stand in equilibrium in the middle of their respective vessels. If the little cups of the key be now filled with mercury, and the crank which works it so placed that the current is reversed a little before the opposite crank comes to its dead point, the machine (having been connected with the poles of a Daniel) will commence working, and may make as many as 100 revolutions in a minute. A Meidinger element keeps the machine in action for months.

1395b. Apparatus for electric osmose.
Prof. Hittorf, Münster.

In each of the three divisions formed in the glass cylinder by the clay plates the electric endosmose (when the vessel is quite filled with the solution of an electrolyte) is produced or prevented according as, on passage of the current, the three openings are free or are closed. With the arrangement it is proved that the transference of the ions is quite independent of the electric endosmose. (Pogg. Ann., Bd. 96.)

d. Effects due to the Force between Currents and Magnets.

1396. Apparatus for showing the Rotation of a Bar-magnet on its axis by the passage through it of an electric current. *George Gore, F.R.S.*

(*See* Proceedings of the Royal Society, Vol. 24, p. 121.)

1397. Apparatus for showing the Rotation of a Copper Wire upon its axis between the poles of two magnets by passing through it an electric current. *George Gore, F.R.S.*

(*See* Proceedings of the Royal Society, Vol. 24, p. 121.)

e. Effects due to the Force between Currents and Currents.

1398. Apparatus for demonstrating the Laws of Ampère.
Geneva Association for Constructing Scientific Instruments.

The mode of suspension used in this apparatus allows the conductor to make a complete revolution.

The current passes from the movable conductor into an annular cup, concentric with the axis of the motion and filled with a conducting liquid.

All the conductors are made of aluminium so as to lessen their weight as much as possible.

The apparatus may be used for a great number of experiments; it is specially adapted for the following demonstrations:—

1. Parallel currents in the same direction attract one another, and those in contrary directions repel one another.
2. Angular currents in the same direction attract one another, and those in contrary directions repel one another.
3. The attraction and repulsion of the same current are equal.
4. A sinuous current acts like a rectilinear current of the same general direction and having the same extremities.
5. A closed current takes a direction perpendicular to the magnetic meridian.
6. A solenoid has the essential properties of a magnet.
7. The elements of the same current repel one another.

The mutual action of magnets and currents is demonstrated by means of the same apparatus, by replacing one of the currents by one or more magnets.

1398a. General Table, by Ampère, with apparatus used by him in the discovery of the action of currents.

College of France, Paris.

1399. Apparatus for demonstrating the action of Metallic Discs in movement upon a metallic wire used as a voltaic conductor. *Professor Daniel Colladon, Geneva.*

Experiment performed on 4th September 1826, in presence of the Paris Academy of Sciences, by Messrs. Ampère and Colladon.

Bulletin de Sciences Mathématiques, by De Férussac, vol. 6, p. 212.

1400. Model of a Circular Railway, for showing the rotation of a metal ball upon it by the passage of an electric current. *George Gore, F.R.S.*

(*See* Philosophical Magazine, Feb. 1859.)

1401. Electro-Spherical Motive Power, with double motion. *G. Trouvé, Paris.*

VII.—APPARATUS FOR REGULATING THE STRENGTH OF ELECTRIC CURRENTS.

1402. Wheatstone's Rheostat, or changeable resistance, for quickly adding or subtracting a low resistance.

Elliott Brothers.

1403. Voltastat and Voltameter combined.

Frederick Guthrie, F.R.S.

Air-tight through the stopper of a cylindrical vessel containing dilute sulphuric acid pap. (1.) Two platinum wires coated with glass. (2.) A long and wide tube open at both ends, the lower end reaching to the bottom of the cylinder. (3.) A tube opening freely beneath the stopper and above by a very fine capillary opening. The platinum wires are enlarged into platinum plates, which are triangles with their apices downwards, and further apart

than their bases. Increase in the current passing by means of the wires between the electrodes causes the liquid to rise higher in the manometer tube, and also by laying bare the electrodes, increases the resistance.

1404. The Voltaic Compensator, an apparatus for maintaining constant the intensity of the electric current derived from any sort of voltaic battery.

Elie Wartmann, Professor of Natural Philosophy in the University of Geneva.

The voltaic compensator is an apparatus which keeps the intensity of the current from any voltaic battery constant. A full description is printed in the number for January 1858 of the "Archives des Sciences physiques et naturelles." In addition to the principal current, which, if constant, would do the work required, there is an auxiliary one, the strength of which is kept down by inserting an additional resistance. This resistance diminishes with the weakening of the principal current, and the consequent increase of the auxiliary current compensates that weakening.

1404a. Regulator, by Foucault. *M. J. Duboscq, Paris.*

1405. Apparatus to make the **Electric Light,** derived from a **Voltaic Battery,** constant in its position and intensity.

Elie Wartmann, Professor of Natural Philosophy in the University of Geneva.

An apparatus called a fixator of electric light, used in the years 1856 and 1857 for lighting the harbour of Geneva. A full description is to be found in the number for December 1857 of the "Archives des Sciences physiques et naturelles." By means of an electro-magnet and of gravity, two points of carbon are placed and kept at such a distance that the light produced by the current of an electric battery may be as bright as possible.

1406. Regulator of Electric Currents, after the plan of M. Mascart. *M. Redier.*

1407. Regulator for the Electric Light. *M. Carré.*

1408. Artificial Charcoal Sticks for the Electric Light. *M. Carré.*

1409. Electric Lamps. These lamps are automatic in their action, in them the carbon points are caused to approach or recede from each other as required, without the aid of clockwork.

Siemens and Halske, Berlin.

VIII.—APPARATUS FOR DETECTING AND MEASURING DIFFERENCES OF ELECTRIC POTENTIAL AND CURRENTS OF ELECTRICITY.

a. Electroscopes and Electrometers.

1410. Two Repulsion Electrometers constructed and used by Van Marum. *Teyler Foundation, Haarlem.*

1411. Small Pocket Electroscope used by **H. B. de Saussure** during his excursions in the Alps.

M. H. Henri de Saussure, Geneva.

1412. Insulating Stand, with **Air Chamber,** artificially dried by sulphuric acid, used in connexion with first portable atmospheric electrometer. *Sir William Thomson.*

Its stand was ordinarily attached to the top of the electrometer, as figured in Nichol's Cyclopædia, Art. Electricity (atmospheric), and in Thomson's Reprint of Papers on Electrostatics and Magnetism, XVI., 263. Sometimes—as in observations to determine in absolute measure the electric force in the atmosphere, on the sea beach, and in boats in Brodick Bay, Isle of Arran (reprint XVI., 281), and, with the assistance of Dr. Joule, on the Links of Aberdeen (British Association meeting, 18)—the stand was detached from the electrometer and laid on the ground at a distance from it with connexion by fine wire to the insulated part of the electrometer, which also was placed on the ground, and was read by observer lying as close to the ground as possible.

1413. Atmospheric Portable Electrometer, No. 2, altered for first trial of divided ring principle for a quadrant marine electrometer, and used successfully on board the "Great Eastern," though not in connexion with the cable, in 1865.

Sir William Thomson.

This instrument has not been repeated, nor described in print, but it may yet do good service at sea. Made by James White, Glasgow.

1413a. Sir Wm. Thomson's Quadrant Electrometer, with most complete adjustments and of most perfect construction.

James White.

A descriptive pamphlet will accompany the instrument.

1414. Atmospheric Portable Electrometer, No. 4, altered to a plan for marine electrometer, which was discarded soon after trial. *Sir William Thomson.*

1415. Atmospheric Portable Electrometer, No. 5. Perfected portable electrometer, on same general plan as No. 1, described fully in Friday Evening Lecture to the Royal Institution, May 18th, 1860 (Thomson's Reprint of Papers on Electrostatics and Magnetism, XVI., 277). Made by James White, Glasgow. *Sir William Thomson.*

1416. Atmospheric Portable Electrometer, No. 10. First of new plan described in report on electrometers and electrical measurements (British Association Report for 1867, Committee on Standards of Electrical Resistance, and Thomson's Reprint of Papers on Electrostatics and Magnetism, XX., 368).

Sir William Thomson.

In this first instrument the attracting disc turns with a micrometer screw instead of moving in a geometrical slide, as in the portable electrometers now made. The receptacle for pumice and sulphuric acid was dangerously placed in the roof. This instrument was designed and first tried in the Island of Arran in 1862. Made by James White, Glasgow.

1417. Attracted Disc Heterostatic Station-Electrometer on same electric principle as latest portable electrometers, but with mechanism inverted. *Sir William Thomson.*

This instrument is of convenient dimensions and general plan for stationary observations of atmospheric electricity and various electrostatic measurements. Made by James White, Glasgow.

1418. Large Portable Electrometer of same general plan as No. 10, altered to measure distance between two metallic conductors giving sparks with electro-motive force measured by another electrometer, in continuation of Smith and Ferguson's measurements. (Proceedings of the Royal Society, 1860, and Thomson's Reprint of Papers on Electrostatics and Magnetism, XIX., 320.) *Sir William Thomson.*

Numerous accurate experiments were made many years ago by this piece of apparatus, but the results have not hitherto been published. Made by James White, Glasgow.

1420. Station Electrometer. *Sir William Thomson.*

This electrometer was used by Professor Everett in his two years series of observations on atmospheric electricity at Windsor, Nova Scotia, described in the Transactions of the Royal Society of London for 1868. Its electric principle is the same as that of No. 8 of the perfected form of portable electrometer of the first kind. (See Thomson's Reprint, xvi. 777.)

1421. First divided Ring (semi-circular) **Electrometer.** *Sir William Thomson.*

This was used for several years in the University of Glasgow, and described in the Accademia Pontificia dei Nuovo Lincei, February 1857, and in Thomson's Reprint, xviii. 311.

The moveable electrified body projects from one side of the bearing wire far enough to travel over the flat semi-circular rings and experience their electric force. It is kept electrified by a fine platinum wire dipping in sulphuric acid, which forms the outside coating of the Leyden jar below it.

1422. Attracted Disc Electrometer, with double micrometer screw, arranged, to give the same period of free oscillation with different forces at different distances. *Sir William Thomson.*

The lower disc is insulated, the upper connected with the metal work of the case of the instrument and of the micrometer screws by a spiral spring by which it is hung. By turning the torsion head the upper end of the spring and the sight marks with movable stops for the lower end of the spring are moved through different distances, of which the former is $1\frac{1}{2}$ times the latter. The instrument exhibited was made 15 or 20 years ago. The present condition of the spiral spring shows that it has become elongated through time, without stress, because the hook at its lower end, bearing the disc, rests firmly against the lower stop, with the stop in its lowest position that the micrometer screws allow.

1423. First Mirror divided Ring (semi-circular) **Electrometer,** used at Kew for recording atmospheric electricity. *Sir William Thomson.*

A specimen of the curve by which it recorded the atmospheric potential is published in Thomson's reprint, xvi. 292. Specimen sheets of its actual work accompany the instrument.

1424. First Trial Apparatus, towards mirror quadrant electrometer. *Sir William Thomson.*

This instrument was first designed for marine use. The mirror and needle are supported on a stretched bundle of silk fibre, as are the needle and magnets of the marine galvanometer. The electric connexion between the needle and the inside coating of the Leyden jar is made by a spiral of fine platinum wire. These peculiarities were tested and found to work moderately well in the trial instrument now exhibited, but have never been repeated; nor does it seem very desirable they should be repeated, as the balancing of the needle on this plan, with sufficient accuracy for good work at sea, would probably be more troublesome than the object would justify. The electric action of this instrument was found so promising that immediately on the same electric plan were constructed instruments for use on land. The shape and dimensions of the suspended needle and of the electrified surroundings of the mirror are precisely the same as those of the quadrant electrometers now made. The improvements upon this original working model consist of geometrical slides for the quadrants, mechanical details regarding the suspension, the substitution of a fine platinum wire hanging down into the liquid in the bottom of a tall Leyden jar for the platinum spiral, and the addition of a replenisher.

1425. Divided Ring (semi-circular) **Electrometer,** described in Nichol's Cyclopædia, article Electricity (Atmospheric). *Sir William Thomson.*

1426. Improved Helmholtz's Quadrant Electrometer. *F. Rob. Voss, Berlin.*

The advantages of this instrument are:—(1.) That the quadrants with the needle and mirror can be easily removed, so that any change in the needle or misplacement of the mirror may be examined with certainty.

1427. Electrometer. *E. Stöhrer, Leipzig.*

1428. Kohlrausch's Torsion-electrometer. *Prof. Wüllner, Aachen.*

1429. Kohlrausch's Sine-electrometer, with two needles of different magnetic momentum. *Prof. Wüllner, Aachen.*

1430. Kohlrausch's Condenser. *Prof. Wüllner, Aachen.*

All three pieces of apparatus were manufactured by Th. Schubart, of Ghent and Marburg.

The detailed description and theory of Kohlrausch's various apparatus may be found as under :—

Poggendorff's Annalen, Vols. 72 and 74 for the torsion-electrometer.
" " Vol. 88 for the sine-electrometer.
" " Vols. 75 and 88 for the condenser.

The apparatus which are exhibited show the forms which Mr. Schubart (late of Marburg, and now of Ghent) now makes. A good description of the

present forms is given in Wüllner's Experimental Physics, Vol. 4, 3rd edition, p. 159, and p. 299.

1431. Edelmann's Quadrant-electrometer.

M. Th. Edelmann, Munich.

1431a. Electrometer for measuring potentials, and particularly the potential of an accumulator at the moment of the discharge.

Prof. Augustus Righi, Bologna.

This electrometer consists of a brass cylindrical box (5), whose inferior base breaks a small circular hole, while the superior is reduced, but at two opposed sectors of 60°. It is carried by two columns of ebonite fixed upon a wood table supplied with level screws. A vertical brass tube rises on the centre of the superior face of the box, and breaks the movable system (3), namely, a double sector of aluminium, which in the apparatus is in part covered by the double sector of the box, suspended by a platina wire, and connected with a plane mirror and a little thin glass. This glass plunges in some liquid, and serves to stop the oscillation. A brass cylinder (6) is fixed under the box, and serves to protect the mirror from the influence of the electricity, which can be transmitted in ebonite columns. The apparatus reposes on a table (7), the upper part of which is covered with zinc, and supported by three insulators; a zinc bell (2), 570 millimeter height, must be placed upon the insulated table (7), to contain the whole apparatus. A metallic wire, covered by an ebonite tube (1), serves to establish the communication between the apparatus and one of the surfaces of accumulation (which can always communicate with the electric machine which serves to charge it); the other surface communicates with the zinc bell. It is necessary to charge the condenser slowly so that the movable system may deviate without oscillation; at the moment of the discharge the effected deflection is read as usual, by the reflection of a mirror on a scale. This deflection is proportional to the square of the difference between the electric potential of the apparatus and that of the zinc bell; otherwise the square root of the deflection measures the difference of potential between the two surfaces of the condenser.

For regulating the sensibility, a brass disc (4) can be put at different heights along the brass tube. If this disc is brought down so as to shut the box, the mirror does not deviate, not even with the strongest charges.

By turning the small ball at the top of the apparatus, the movable system is lowered or raised. If the brass piece which is under the small ball (in Fig. 3) be turned instead, the aluminium double sector is displaced horizontally. Finally by turning the upper part of the box, the mirror is turned towards the hole in the cylinder 6.

1431b. An Induction Electrometer.

Prof. Augustus Righi, Bologna.

A caoutchouc tube carrying many copper rings is wrapped round the non-insulated pulleys (2, 4). If the insulated inductor (1) is charged, the rings go from 2 to conductor 3, with charges of contrary sign, and these charges remain in the insulated conductor 3. For, as the rings touch the conductor 3 by means of a little pulley placed in its interior, the charge preserved by any single ring is neutralized. Briefly, for a very little charge of the inductor, the conductor 3 acquires a sufficient charge, that can be shown by a gold leaf electroscope. If the inductor is uncharged, and the pulleys and

the rings are of the same metal and very clean, the conductor 3 remains uncharged.

In open places the conductor 3 is charged by the sole influence of atmospheric electricity.

1432. Ronalds' Electrical Apparatus, as employed by him at the Kew Observatory; consisting of a principal conductor, with its glass support, umbrella, and heating apparatus; its voltaic collecting lantern; Volta's electrometers and sights; a Henley electrometer; a Gourgon galvanometer; a discharger, or spark measurer; and a Bennet's gold-leaf electroscope.

Kew Committee of the Royal Society, Kew Observatory.

Apparatus erected in the equatorial room of the Kew Observatory, in 1843, by Mr. Francis Ronalds, for the purpose of observing atmospheric electricity, described in the British Association Report for 1844.

It consists of a principal conductor, which is a stout copper tube, passed through a large aperture lined with sealing-wax in the roof of the building in which the instrument was placed, and carrying an inverted copper tray, to exclude rain.

The tube is supported by a stout glass core, which is kept in a dry state by a copper funnel passing up its interior, kept constantly heated by a small lamp.

A second lamp is enclosed in a Volta's collecting lantern, fixed to the top of the collecting tube.

To the cross arms at the base of the tube are attached severally:—Volta's electrometers with ivory scales, and sights for accurately determining the angles of the deflection of the straws; a Henley, or quadrant electrometer; a galvanometer, by Gourgon (the property of Sir C. Wheatstone); a discharger, or spark measurer; and a Bennet's gold-leaf electroscope.

Continued regular observations were made with these instruments for several years.

The wooden stand now exhibited was not the original table upon which they were placed; that, a fixture in the Observatory, having been destroyed.

The Henley electrometer has also been replaced by a less perfect instrument.

1433. Spark Measurer, designed by Major Malcolm, R.E., to show the striking distance of spark from tension exploders.

School of Military Engineering, Chatham.

1433a. Sheathed Electroscope. *Prof. Beetz, Munich.*

1433b. Bifilar Electroscope, with copper and zinc condenser-plates for showing Volta's fundamental experiments, and tourmaline for showing pyro-electricity. *Prof. Beetz, Munich.*

1434. Thomson's Divided Ring Electrometer and **Gauge,** formerly in use for recording atmospheric electricity, at the Kew Observatory.

Kew Committee of the Royal Society, Kew Observatory.

This instrument, which consists of two parts, the electrometer and the gauge, was erected at the Kew Observatory in 1861, in connexion with a photographic recording apparatus, and worked there for about four years,

producing daily records of the fluctuations, &c. of atmospheric electricity, which were discussed by Professor Everett, and the results published, together with a description of the instrument, in the Philosophical Transactions for 1868, Pt. I.

It has since been replaced by an improved quadrant electrometer.

1435. Singer's Gold Leaf Electroscope, for lecture purposes. Large size. *Elliott Brothers.*

1436. Quadrant Electrometer, being a modification of Sir W. Thomson's delicate quadrant electrometer, used for measuring the difference of potential between two conductors.

Elliott Brothers.

1437. Peltier Electrometer, for measuring the electrical tension of a charge by the repulsion of a light aluminium needle, which receives a directive force through a very small magnet attached to it. *Elliott Brothers.*

1438. Capillary Electrometer, after Lippmann.

R. Jung, Heidelberg.

A glass tube *a*, filled to a height of about 85 cent. with mercury, and ending below in a fine point, dips in a cylinder *b*, so that its point presses spring-wise against the wall, where there is a microscope *c* placed horizontally. The cylinder contains mercury in its lower part, and dilute sulphuric acid about the point of the tube; and in the mercury terminates one pole, protected by a glass tube from the sulphuric acid. Above, the long tube is connected with a small glass bow, in which a platinum wire is fused, which, reaching down into the mercury in the tube, forms the upper electrode. The other end of the bow is connected by caoutchouc tubing with an air press, which, on its other side, is connected with a manometer. A little mercury is first forced through the fine point by means of the press. The microscope is then so placed that the zero point of the eye-piece micrometer coincides with the image of the meniscus of mercury in the capillary tube; then the electric source to be measured is brought into the circuit of the apparatus, its negative pole being connected with the upper electrode. The mercury forthwith retires, and can only be brought back by a determinate pressure with the press.

1439. Coulomb's Torsion Balance, for measuring the potential of electricity. *Elliott Brothers.*

1439a. School Form of Coulomb's Torsion Balance.

Harvey, Reynolds, and Co.

b. Galvanometers.

1440. Galvanometer with variable resistance.

The Director of the Physical Laboratory of the University of Groningen.

This galvanometer can be used for hydro-electric as well as thermo-electric currents. By its aid the dependence of the sensibility of a galvanometer on its resistance can be demonstrated.

1441. Reflecting Astatic Galvanometer, with coils of low resistance, and with telescope and scale, for measuring thermo-electric currents of very low intensity. Focal distance of telescope and scale about three metres. Made by Ruhmkorff, of Paris.

George Gore, F.R.S.

1442. Galvanometer, by **Colladon,** with coils insulated by a special method. This instrument was used by the inventor for measuring the intensity of currents produced by electric friction machines, and by the clouds, in 1826, and by electric fish, in 1831. *Professor Daniel Colladon, Geneva.*

The inventor used this same galvanometer in 1831, for studying the distribution of the electric poles upon torpedoes, and the strength of currents produced by animal electricity.

Annales de Chimie et de Physique, 1826, vol. 33.

Péclet, Traité de Physique, 1832, vol. 2, p. 221 to 225.

Mémoires de l'Académie Royale des Sciences, Institut de France, vol. 10, p. 74.

1443. Balance Galvanometer, giving indication of current in grains or other weights in scale pans, which may be adjusted to any standard. Invented by contributor in 1848.

William Sykes Ward.

1444. Galvanometer, designed by **Colladon** for **Currents** of **Electrical Statics.**

Geneva Association for Constructing Scientific Instruments.

Apparatus for demonstrating that the electricity drawn from friction machines, from the clouds, &c., produces currents, of which the direction and the intensity are measured by the deviation of the magnetic needle of a galvanometer.

1445. Marine Galvanometers used on board H.M.S. "Agamemnon" and the U.S. Frigate "Niagara," in the Atlantic Cable Expeditions of 1858. *Sir William Thomson.*

A light mirror, weighing 30 milligrammes and 9 millimetres in diameter, with single needle cemented to its back, suspended by stretched platinum wire in centre of field of coil composed of two bobbins of fine copper wire. Micrometer screws to adjust zero by torsion of upper and lower parts of platinum wire. The first words transmitted across the Atlantic were from the "Agamemnon" approaching the Irish coast, and were read on one of these instruments on board the "Niagara" approaching Newfoundland. (Encyclopædia Britannica, Art. Telegraphs (Electric), VII. 6, and VIII. 4.) Made by White and Barr (now James White), Glasgow.

1446. First Instrument for **recording Signals** through **Long Submarine Cables,** by curve of perforations produced by sparks from a Ruhmkorff coil guided by a platinum wire moved by a needle under the influence of the varying current from the cable. *Sir William Thomson.*

This instrument was sent out for use on the first Red Sea cable (1859), but did not arrive until after the failure of the cable. It returned dismantled, and was never set in action again. It has been superseded by the siphon recorder. Made by White and Barr (now James White), Glasgow.

1446a. One of the First Mirror Galvanometers, made for the reading of messages through submarine cables, and used for that purpose at Newfoundland in 1858. This galvanometer has an arrangement for altering the intensity and direction of the directing force by a double motion of the directing magnet. One for varying its distance from the suspended needle and mirror, the other giving the magnet a motion in azimuth. This arrangement is still used in the Astatic Mirror Galvanometer for testing sub-marine cables. *Sir William Thomson.*

1447. Ironclad Marine Galvanometer, used on board the "Great Eastern" in the Atlantic Cable Expedition of 1866, and subsequently by Mr. Willoughby Smith in the Mediterranean and Red Sea. *Sir William Thomson.*

This instrument is the first ironclad marine galvanometer, and the first with suspension by stretched silk fibre instead of platinum wire. Made by James White, Glasgow.

1447a. A Differential Galvanometer, constructed specially for testing the locality and nature of faults in submarine cables. It is the first instrument in which *shunts* were used for practical electrometric purposes. A shunt is applied to one of the wires of the coil so as to multiply the reading of a rheostat *ten* times. It also was used for telegraphic reading purposes and for measuring the discharge from cables. It was made in 1858, and was in constant use for many years.

W. H. Preece, General Post Office, London.

1447b. Thomson's Mirror Galvanometer, with hinged coils, and **Shunt** for same. *Warden, Muirhead, and Clark.*

1448. Absolute Galvanometer or Magnetic Dynamometer. *Frederick Guthrie, F.R.S.*

A current traverses in succession four spirals embracing soft iron cores. Two of the so formed electro-magnets are fixed and two movable together in a horizontal plane by means of suspension from a torsion thread. The spirals are such that the magnets repel one another. If, when no current is passing, a beam of light reflected from a mirror attached to the movable pair falls in a certain place, then when a current passes the torsion screw head must be turned so as to force the magnets up to the same distance as before. The repulsion or angular torsion is proportional to the square of the current.

1449. Galvanometer for measuring large currents in definite units. Graduated in Weber's for use with the electric light, &c., and in ounces of silver deposited per hour, for use in electro-plating or in other forms of actual work. *John T. Sprague.*

1450. Patent Universal Galvanometer, indicating current and resistance in definite units of measurement.

John T. Sprague.

This galvanometer contains four circuits, having 1, 10, 100, and 1,000 fold degrees of action on the needle, enabling it to be used for large or small currents. The patent dial is graduated to indicate the current in actual units, either the British Association Weber, or in chemical equivalents. It is also graduated to show the total resistance of the circuit in Ohms without the aid of a resistance instrument when used with a Daniell cell. By using a fixed resistance it shows the electromotive force of the circuit in Volta.

1450a. Galvanometer for Projections.

M. J. Duboscq, Paris.

1450b. Galvanometer, for thermo-electric currents.

Luizard, Paris.

1451. The Rhé Electrometer of Marianini, for observing electric discharges between the atmosphere and the earth.

Robert James Mann, M.D.

This instrument was planned by Professor Melsens. It contains a coil of copper wire which is to be made continuous with the system of a lightning rod, or with the earth wire of a telegraph line. When an electric spark passes through the coil a soft iron bar in its interior is magnetised, and a traversing magnetic needle pivoted above the coil is then deflected out of the north and south line of the earth's magnetism towards either the east or west. When the interior iron has been magnetised it must be replaced with a neutral bar before another observation can be made.

1452. M. Becquerel's Electro-magnetic Balance.

Conservatoire des Arts et Métiers, Paris.

1453. Pouillet's First Compass for Lines and Tangents. *Conservatoire des Arts et Métiers, Paris.*

1454. Sine-Tangent Compass.

Siemens and Halske, Berlin.

1455. Aperiodic Galvanometer, with telescope and scale.

Siemens and Halske, Berlin.

1456. Inclination Galvanometer. *Dr. Werner Siemens.*

Intended for use particularly with the selenium galvanometer (No. 895). The coil of the galvanometer is wound horizontally; the needle vibrates in a vertical plane and carries a mirror which reflects the image of a finely photographed scale (placed above) into the optical axis of a microscope.

1457. Galvanometer for testing Lightning Conductors, for the Prussian Royal Engineers. *Keiser and Schmidt, Berlin.*

1458. Mirror Multiplier. *E. Stöhrer, Leipzig.*

1459. Galvanometer, showing both inclination and declination. *E. Stöhrer, Leipzig.*

The broad brass frame which carries the magnetic needle can be turned about its axis; likewise the vertical support in its base. Thus the needle

can be brought to move in various planes, and the altered action of the force measured by observation of the vibrations.

1459a. Current Measurer, with arrangement for measuring very strong electric currents. *Baur and Haebe, Stuttgart.*

1460. Edelmann's Mirror-galvanometer for absolute measurements. *M. Th. Edelmann, Munich.*

1461. Large Wiedemann's Galvanometer. *M. Th. Edelmann, Munich.*

1462. Small Wiedemann's Galvanometer. *M. Th. Edelmann, Munich.*

1463. Edelmann's Compensation-galvanometer. *M. Th. Edelmann, Munich.*

1464. Edelmann's Lecture-galvanometer. *M. Th. Edelmann, Munich.*

1465. Edelmann's Small Mirror-galvanometer. *M. Th. Edelmann, Munich.*

1466. Edelmann's Pocket Compasses, with absolute measurements for electro-therapeutics. *M. Th. Edelmann, Munich.*

1467. Du Bois Raymond's Astatic Magnet. *M. Th. Edelmann, Munich.*

1468. Ordinary Compensator. *M. Th. Edelmann, Munich.*

1469. Edelmann's Induction Galvanoscope. *M. Th. Edelmann, Munich.*

1470. Large Galvanometer for **Electro-therapeutic Purposes.** *M. Th. Edelmann, Munich.*

1471. Differential Galvanometer, very delicate, with two coils. (Becker, London.) *H. Lloyd, Trinity College, Dublin.*

1472. Electro-Dynamometer. Apparatus to determine the strength of electric currents by measuring the action between different parts of the current itself. *H. Lloyd, Trinity College, Dublin.*

1473. Apparatus for covering wire with silk for electric purposes. *H. Lloyd, Trinity College, Dublin.*

1474. Apparatus to illustrate some of the laws of electrical rotation of Faraday and Ampère. *Yeates & Sons.*

1475. Tangent Galvanometer. *James How & Co.*

1476. Thomson's Astatic Reflecting Galvanometer, round glass case, for lecture purposes. *Elliott Brothers.*

The most sensitive instrument yet constructed for detecting the presence of a current and measuring its magnitude.

1477. Thomson's Astatic Reflecting Galvanometer, in square brass case, made by Elliott Brothers. *Prof. W. F. Barrett.*

The upper coil of this galvanometer has a very high resistance, the lever a very low one; the coils are used independently.

1478. Set of Shunts, for use with galvanometers, to reduce the angle of deflections of the needle 10, 100, or 1,000 times by shunting off the current, so that only $\frac{1}{10}$, $\frac{1}{100}$, or $\frac{1}{1000}$ of the current passes through the galvanometer, and the remainder through the shunts. *Elliott Brothers.*

1479. Simple Horizontal Galvanometer, coiled with stout wire of low resistance, intended especially to show thermo-electric currents. *Elliott Brothers.*

1480. Tangent Galvanometer, designed by Gaugain, for measuring electro-motive force, resistance, &c. *Elliott Brothers.*

The instrument is composed of two coils, separated by a distance equal to one half their diameter; contains three sections of stout wire, which can be connected at pleasure. This instrument can be used with very powerful currents.

1481. Speaking Galvanometer, used for signalling through submarine cables. The mirror and magnet are doubly suspended; glass in front and back protect the mirror and magnet from draught and dust. *Elliott Brothers.*

1482. Oil Vessel Galvanometer, as used in military schools, for testing and signalling. *Elliott Brothers.*

The coils consist of two sections of high and low resistance, which can easily be brought into circuit by a switch in front of the instrument. To reduce the oscillations of the needle, the instrument is provided with a glass vessel for liquids, into which the vane of the needle dips.

c. Electro-Dynamometers.

1483. Electro-dynamometer, for measuring electric currents which are constantly being reversed in direction. Made by Dr. Meyerstein, of Göttingen. *George Gore, F.R.S.*

1484. Edelmann's Absolute Dynamometer,
M. Th. Edelmann, Munich.

1485. Fine-wire Electro-dynamometer.
M. Th. Edelmann, Munich.

d. VOLTAMETERS.

1486. Voltameter.

Geneva Association for Constructing Scientific Instruments.

The tube of the voltameter is divided on glass into sixteenths of cubic centimetres.

1486a. Voltameter for teaching.

Physical Institute (Univ. of Giessen), Dr. Buff.

This apparatus for the decomposition of water is described in Liebig's Annalen, Vol. 93, p. 256. It is intended to render the gases evolved available for analysis or otherwise.

The connecting piece, fitted above with caoutchouc tubing, serves for ordinary purposes. By means of the apparatus, not only may the reconstitution of water be shown, but pretty intense phenomena of heating and ignition, *e.g.*, of a steel spring. For such experiments 12 Bunsen pairs are necessary, connected in series.

1486b. A Silver Voltameter, with platinum vessel.

Prof. Beetz, München.

A convenient modification of the Poggendorff voltameter.

1486c. Mercury Voltameter.

The Physical Science Laboratory of the Technological Institute at St. Petersburg (Russia).

This apparatus is intended for measuring the strength of currents by the reduction of mercury. It consists of two electrolytic glass bowls joined by a pipe, and an apparatus for measuring the reduced mercury volumetrically. A more detailed description, with drawing and directions for use, accompany the instrument.

IX.—APPARATUS FOR MEASURING ELECTRICAL RESISTANCE AND CAPACITY.

1487. Wheatstone's Bridge of the simplest construction, especially used for conductivity and low resistance tests. The bridge is provided with one pair of equal resistances and one standard resistance. *Elliott Brothers.*

1488. Thomson's Circular Sliding Resistance, of greatest importance in cable tests in connexion with the quadrant electrometer for measuring resistance, tension, or potential of cables and batteries, and for detecting faults in cables.

Elliott Brothers.

Megohm or 1 million Ohms resistance is indispensable for measuring very high resistances, for determining the constant of galvanometers, &c.

1489. Plate, showing **Dr. Bosscha's Method** of determining the **Ratio of two resistances,** with explanatory note.

T. Bosscha, Professor, Royal Polytechnic School, Delft.

1490. Plate, showing **Dr. Bosscha's Method** of determining the **Ratio of two electro-motive forces,** with explanatory note.

T. Bosscha, Professor, Royal Polytechnic School, Delft.

1491. Cylindrical Condenser for measuring Capacity in absolute electrostatic units. *Sir W. Thomson.*

1492. Adjustable Disc Condenser, also used as a spark micrometer. *Sir W. Thomson.*

1492a. Early Rheostat, given by Faraday to Sir Charles Wheatstone.

Wheatstone Collection of Physical Apparatus, King's College, London.

1492b. Divided Condenser, as designed by Major Malcolm, R.E., for comparing the electrostatic capacities of cables, the electro-motive force of batteries, &c. *Elliott Brothers.*

This condenser is in 12 subdivisions, as follows, viz.:—·001, ·002, ·002, ·005, ·01, ·01, ·02, ·05, ·1, ·1, ·2, ·5 = 1 microfarad; so that any capacity from $\frac{1}{1000}$ to 1 microfarad can be obtained.

1493. Rheostat with large copper wire.

Wheatstone Collection of Physical Apparatus, King's College, London.

1494. The Original Wheatstone's Bridge.

Wheatstone Collection of Physical Apparatus, King's College.

1494a. Rheostat (Agometer), with platinum wire. Invented by M. H. Jacobi, in the year 1841.

Physical Science Cabinet of the Imperial Academy of Sciences at St. Petersburg.

1495. Universal Resistance-Box.

Siemens and Halske, Berlin.

1495a. Great Lane's Measuring Flask.

Warmbrunn, Quilitz, & Co., Berlin.

1496. Complete Bridge. *Siemens and Halske, Berlin.*

1497. Edelmann's Small Rheochord.

M. Th. Edelmann, Munich.

1498. Resistance Apparatus with Weber's absolute units.

M. Th. Edelmann, Munich.

1499. Universal Compensator, for measuring resistances and electro-motive forces. *Prof. Beetz, Munich.*

The apparatus exhibited by Prof. Beetz was manufactured from his plans by M. Th. Edelmann.

1499a. Compensator, by Froment.
Polytechnic School, Paris.

1500. Post Office Resistance Coil, as used by the Government telegraph authorities, for testing the resistance of telegraph lines, cables, batteries &c. *Elliott Brothers.*

These coils are constructed on the Wheatstone's bridge principle, and the arrangement allows of the measurement of resistances from $\frac{1}{100}$ to 1,000,000 Ohms.

1501. Dial Resistance Coil, for testing the resistance of telegraph lines, cables, batteries, &c. *Elliott Brothers.*

These coils are capable of greater accuracy than other resistance coils. For each dial only one plug is used to bring the desired resistance in circuit, or every change, therefore, the same number of plugs is necessary.

1502. Preece's Balance, for comparing resistances in connexion with a set of resistance coils. *Elliott Brothers.*

This instrument is on the principle of the Wheatstone's bridge, and contains four pairs of equal resistances, a commutator, and two keys.

1503. Set of Resistance Coils, German silver, with Wheatstone's bridge, for testing the resistance of telegraph lines, cables, batteries, &c. These coils allow of measurements of resistance from $\frac{1}{100}$ to 1,000,000 Ohms. *Elliott Brothers.*

1504. British Association Unit or Ohm, of German silver wire, equal to 10 absolute electro-magnetic units, the standard of electrical resistance. *Elliott Brothers.*

1504a. Large Set of Resistance Coils, with Bridge (a new form and arrangement). *Warden, Muirhead, and Clark.*

1504b. New combined Set of Thomson and Varley's Resistance Slides (a new form and arrangement).
Warden, Muirhead, and Clark.

1504c. Set of Resistance Coils (small portable set), containing 10,000 B A units in the aggregate, and set of proportional coils for same. *Warden, Muirhead, and Clark.*

1504d. Condenser, 20 microfarads.
Warden, Muirhead, and Clark.

1504e. Small portable Standard Condenser, capacity 1 microfarad in aggregate, divided in : 1 : 2 : 3 : 4 microfarads.
Warden, Muirhead, and Clark.

1504f. Standard Condenser, $\frac{1}{3}$ microfarad.
Warden, Muirhead, and Clark.

1504g. Clark's Standard Element.
Warden, Muirhead, and Clark.

X.—STANDARDS OF COMPARISON FOR MEASUREMENT OF ELECTRICAL MAGNITUDES.

1505. Weber's Resistance Coils, No. 3 and No. 5, certificated to represent the following resistances:—

No. 3 = 60717×10^5 Weber's absolute units.
No. 5 = 59440×10^5 " "

T. Bosscha, Professor, Royal Polytechnic School, Delft.

Comparisons of these coils were published by Dr. Schröder van der Kolk in Poggendorff's Annalen, vol. 110, p. 465.

The coil No. 3 was used in the first determination of the electro-motive force of a Daniell's cell in absolute measure, executed in 1857 by Dr. Bosscha. This electro-motive force was found to be 1026×10^8 metres absolute units. Applying Sir William Thomson's theorem (Phil. Mag., Series IV., vol. ii. p. 557), the mechanical equivalent of heat derived from this result is 432·1 as compared with MM. Favre and Silbermann's determination of the heat generated by the action of zinc on sulphate of copper; 419·5 as compared with Mr. Joule's experiments on the heating power of a Daniell's cell (Phil. Mag., Series IV., vol. iii.), discussed in Poggendorff's Annalen, vol. 103; 437·3 as compared with similar experiments of Professor Lenz (Pogg. Ann., vol. 59, p. 203), discussed in Poggendorff's Annalen, vol. 108, p. 162; and 421·1 as compared with similar experiments of Mr. Joule, related in "Memoirs of the "Lit. and Phil. Soc. at Manchester," vol. vii. p. 94, and discussed in Poggendorff's Annalen, vol. 108, p. 168.

1506. Siemens' Resistance-Unit.
Siemens and Halske, Berlin.

1506a. Normal Mercury Unit in glass spiral.
Siemens and Halske, Berlin.

1507. Conductivity Apparatus, for comparing the conductivity of wires of copper, or any other metal or alloy, with 100 inches of pure copper weighing 100 grains, 200 inches weighing 100 grains, or 300 inches weighing 100 grains. The conductivity is determined by resistance, length, and weight.
Elliott Brothers.

XI.—APPARATUS FOR THE APPLICATION OF ELECTRICAL PRINCIPLES TO PRACTICAL PURPOSES.

a. Telegraphic Apparatus.

1508. Two Drawings of plans, sections, and elevations of machinery of Sir C. Wheatstone's proposed scheme for a submarine telegraph cable, 1840. *Robert Sabine, Regent's Park.*

1508aa. Electric Telegraph. A portion of the original copper wire and glass tube buried by Sir Francis Ronalds in 1818 for the purpose of his then new discovery of electric telegraphy; found after several months' search by the lender.

Captain Henry Hill.

1508a. Portion of the **First Submarine Telegraphic Cable.** This cable was laid by Mr. T. R. Crampton, C.E., in 1851, and established the practicability of submarine telegraphy.

Thomas Russell Crampton, Westminster.

Submarine telegraphy in 1851 was deemed by most engineers and the public to be visionary if not impracticable.

Its extension over the whole world since its first practical introduction in 1851, has been immense, and the advantages to the world at large incalculable. It was established in the following manner :—Various propositions were from time to time put forth to effect the object, but few people were prepared to take the risk until a company was formed having most influential men on the direction, who advertised in the usual manner for subscriptions. Such, however, was the want of confidence felt in the scheme, that only about two per cent. of the necessary capital was subscribed, and this money was consequently returned to the applicants. Notwithstanding this apathy of the public some of the directors and their friends did not cease to entertain a full conviction of its possibility, and they subsequently consulted Mr. T. R. Crampton, C.E., on the subject, and offered to assist towards providing the funds if he felt sufficiently confident of ultimate success. Mr. Crampton undertook the entire charge and responsibility of the form, construction, and laying of the cable, and also took upon himself rather more than one half the pecuniary risk, the other half of the money being found by Lord de Mauley, Sir James Carmichael, Bart., Messrs. Davies Son and Campbell (the solicitors of the Company), the Hon. F. W. Cadogan, and Mr. Haddon.

The cable was in the same year (1851) successfully laid between Dover and Calais by Mr. Crampton.

The great risk the parties ran can be better appreciated from the fact that three successive attempts by other parties to establish submarine cables between England and Ireland occurred soon afterwards, which all failed.

The above-named gentlemen were also instrumental in laying the next successful cable between Dover and Ostend.

This latter was constructed in a similar manner to the original one, and they are both still in operation.

No fundamental change has yet been effected in the form and mode of construction of heavy cables, thus proving satisfactorily that the first type of heavy submarine cable laid upwards of twenty-five years ago is practically right in principle.

1508b. A portion of the **first line of Telegraph,** laid by Cooke and Wheatstone in 1837 between Euston and Camden stations. It consists of five wires and was worked with their earliest or "hatchment" dial instrument.

Latimer Clark, Westminster.

1419. Part of **Cooke** and **Wheatstone's First Working Telegraph.** *Edinburgh Museum of Science and Art.*

1680. Specimen of the First Telegraph Line, 1837.
R. S. Culley, Esq.

This specimen of the first Telegraph line was dug up on the railway incline between Euston and Camden. It was laid down in connexion with the first experiments made with Cooke and Wheatstone's earliest instrument in 1837.

1508c. A portion of the **original Telegraph,** laid by Sir Francis Ronalds in 1816, in his garden at Hammersmith, and described in his book in 1823. *Latimer Clark, Westminster.*

The original wooden model of the dial of the instrument used with the above telegraph.

1508d. Two Photographs of the **Telegraph Apparatus** used by **Gauss and Weber.**
Physical Institute of the University of Göttingen (Prof. Dr. Riecke).

The one of the photographs represents the magnetic inductor which serves for giving the signals, the other the unifilar magnetic rod with multiplier serving for receiving the signals.

SPECIAL COLLECTIONS ILLUSTRATING THE HISTORY OF ELECTRIC TELEGRAPHY, CONTRIBUTED BY H.M. POSTMASTER GENERAL.

1508e. Cooke and Wheatstone's Earliest Needle Instrument, 1837.

The letters are indicated by the convergence of two needles. The five line-wires required for the instrument were inserted in grooves in a triangular piece of wood, and wire laid underground.

1509. Cooke and Wheatstone's Four-Needle Telegraph, 1838.

Some of the letters are indicated by the convergence of two needles, as in the five-needle instrument, the rest by one or more movements of the needles to the right or left.

1510. Alarum with Centrifugal Hammer. Used in connexion with Cooke and Wheatstone's first needle instruments.

Moved by wheelwork and mainspring; released by an electro-magnet. Used in connexion with Cooke and Wheatstone's first needle instruments.

1511. Single-Needle Instrument, modern form, with drop handle.

Used by the Electric Telegraph Company.

1512. Double-Needle Instrument, modern form.

Used by the Electric Telegraph Company.

1513. "Thunder Pump."

Henley's Magneto-Electric Machine, used for ringing alarums, etc., commonly known as the "Thunder Pump." Used by the Electric Telegraph Company.

1514. Portable Double-Needle Instrument, which could also be used for testing wires.

Each of the needles worked by two finger keys behind the case. Used by the Electric Telegraph Company.

1515. Model Double-Needle Instrument with a Four-Pedal Commutator, 1849.

Model Double-Needle Instrument with a four-pedal commutator, 1849.

1516. Old Form of Double-Needle Instrument.

Old form of Double-Needle Instrument with six-inch coils and crutch handles.

1517. Series, showing the several Forms **of Coil and Needle** used by the Electric Telegraph Company.

a. The original form. 6-inch coils.
b. Holmes' diamond needle. 1-inch, 1848.
c. Clark's Needle.
d. S. A. Varley's coil with soft iron needle magnetized by induction.
e. Spagnoletti's do.
f. Brittan's do.

1518. Early Train Signalling Instruments.

a. Cooke's first " block " instrument used on the Norfolk Railway, about 1845.
b. Step by step train indicator used on the London and South-western Railway.
c. Do. do. South-eastern Railway.
d. Signalling instrument used for starting and stopping the endless rope by which the Blackwall Railway was first worked, about 1840.

1519. Henley's Magneto-electric Double-Needle Instrument, 1848. Used by the British and Irish Magnetic Telegraph Company.

The needles only move on one side of their vertical position, and the signals are made up of the single and combined movements of the two needles.

This instrument requires two line wires, and is worked by the magneto-electric current generated by moving the handle or handles.

The interior needles are small straight bar magnets, playing between the semicircular pole pieces of an electro-magnet. The needle remains on the side on which it is left by the last current which passes through the coils, and does not return to its vertical position by gravity, as in Cooke and Wheatstone's needle instrument.

1520. Henley's Magneto-electric Single-Needle Instrument, 1848. Used by the British and Irish Magnetic Telegraph Company.

The dots and dashes of a modification of the Morse alphabet are represented by the duration of deflection of the needle on *one* side only of its normal position. It is worked by the magneto-electric current generated by moving the handle. Its construction is precisely similar in principle to Henley's magneto-electric double-needle instrument. It was used on less important lines than those on which the latter instrument was adopted.

1521. Highton's Needle Telegraph, 1848. Used by the British and Irish Magnetic Telegraph Company

A horseshoe or circular magnet within a circular coil, and worked by a reversing key, is used.

The signals are similar to those of Cooke and Wheatstone's single needle, but a different alphabet is adopted.

Needle and coil used with this instrument.

1522. Highton's Needle Telegraph, smaller form. Used by the British and Irish Magnetic Telegraph Company.

Identical in construction with the original form, which it superseded.

1523. Highton's Needle Telegraph, last form. Used by the British and Irish Magnetic Telegraph Company.

With key detached. Identical in construction with the two former instruments, but the signalling key is detached from the indicating portion, and placed near the edge of the desk before the operator for greater convenience of working.

1524. Reversing Signalling Key, for Highton's simple Needle Telegraph. Also used with Bright's Bell Instrument.

This is a substitute for the drop handle Commutator of Cooke and Wheatstone's needle instrument. When the right-hand key is depressed a current in one direction is sent out to the line, and the pointer of the indicating instrument moves to the right. When the left-hand key is depressed a current in the opposite direction is sent, and the pointer moves to the left.

1525. Bright's Bell Instrument, 1855, **with Relay.** Used by the British and Irish Magnetic Telegraph Company.

The simple needle alphabet is produced by striking two bells of different tones, the hammers being actuated by electro-magnets worked by a relay and local battery. The relay is double-acting, and consists of two electro-magnetic bobbins placed side by side, their ends being furnished with pole pieces turning inwards. Between these pole pieces at each end of the bobbins the ends of permanently magnetised needles pivoted on vertical axes play; these needles are so placed as regards their polarity, that a current in one direction moves the needle which closes the local circuit of the right-hand bell, and a current in the opposite direction moves the other needle which closes the local circuit of the left-hand bell. The signalling key used with this instrument is similar to that used with Highton's single needle. This instrument superseded Henley's magneto-electric system.

1526. Bright's Direct Bell Instrument, 1870. (Model.)

Model of a Bright's bell instrument, in which the bells are struck by hammers attached to the magnetic needles of the relay.

1527. Highton's Gold Leaf Telegraph, 1846.

A movable conductor formed by a strip of gold leaf is placed in proximity to one pole of a permanent bar magnet, and moves to the right or left of its normal position according to the direction of the current passing through it. It was designed as a substitute for the needle and coil of Cooke and Wheatstone's instrument, but was never brought into practical use.

[This apparatus was described by Cumming in 1827, in his "Electrodynamics"; it is also mentioned in the *Encyclopædia Britannica*, 7th ed., Art. "Voltaic Electricity," and in the treatise on "Electromagnetism" in the *Library of Useful Knowledge*, 1832.]

1528. Plunger Signalling Key, used by the London District Telegraph Company.

This key is used instead of the drop handle key of Cooke and Wheatstone's instrument, or the two-pedal key in Highton's instrument. An ordinary single-needle indicator is used in connexion with it.

1529. Keys used with Bain's and Morse Telegraphs, by the Electric Telegraph Company.

a. Simple spring key.

b. Key for sending a short reversal after each signal, two sets of batteries being required. When the key is up, the line wire is connected to the receiving apparatus.

c. Wheel key. A constant current is reported on the line, and signals are made by depressing the key and thus reversing the current. A switch is used for making the necessary alterations to the connexions for sending and receiving.

1530. Switches or Commutators for making Changes of Wires in Circuits. Used by the Electric Telegraph Company.

a. Earliest switch for double needle. Instruments fixed at Normanton.

b. Tumbler switch.

c. Umschalter or Universal switch.

1531. Morse Embosser, about 1853. Used by the Electric Telegraph Company.

This superseded the Bain instrument and has in its turn been superseded by the inkwriter.

The dots and dashes of the Morse alphabet are made by a rounded steel point fixed at one end of a lever, the other end being furnished with an armature and attracted by an electro-magnet worked by a relay and local battery.

1532. Bain's Chemical Telegraph as used by the Electric Telegraph Company in 1850 in place of the double needle.

The paper ribbon was prepared with yellow prussiate of potash and nitrate of ammonia; the style is of iron. The Steinheil code, dots in two parallel lines, was occasionally used, but was entirely superseded by the Morse code of dots and dashes.

1533. Various forms of Ink-writers. (Old.)

a. Breguet's ink-writers.

b. Ink-writer with inking pad and reservoir.

c. Do. do. ink bottle.

1534. Varley's Mill. 1855. Used by Electric Telegraph Company.

This contrivance was used in connexion with relays and translators. When a current passes through the coils the armature is attracted rapidly in the usual way, but when the current ceases the armature returns slowly to

its normal position, by the intervention of a wheel, pinion, and fly, thus lengthening the contact between the line lever and the spacing battery. This is now effected by utilising the extra current from the magnet.

1535. Andrews' "Pump Relay" or "Spacer," used by the United Kingdom Telegraph Company.

This is a contrivance to produce a similar result to Varley's mill. A loosely fitting piston with a ball valve moving in a cylinder filled with oil is used instead of the fly.

1536. Zinc Sender, used by Electric Telegraph Company.

Used for sending a short reversal after each signal in the Morse system, to assist in discharging the line wire.

The coils of this apparatus are wound with fine wire of high resistance, and are placed as a "leak" or derived circuit on the line wire at the sending end; its action is identical with that of a polarised relay. A single current Morse key is used. When this is depressed a portion of the current passes through the coils and moves the tongue of the relay over in contact with the screw stop which is connected to the reversing battery, the other pole of this battery being in connexion with the earth.

The back stop of the Morse key is in permanent electrical connexion with the tongue of the relay, and thus, when the key is raised and its lever comes into contact with the back stop, a reverse current will pass out to the line; but a portion of this reverse current also passing through the coils of the zinc sender will immediately move the tongue to the opposite side, the stop against which it rests being in connexion with the relay of the receiving apparatus. Thus after each reversal following a marking current the instrument is in a position for receiving, and the receiving station can stop the sending station during transmission. A smaller battery than the sending one is used for the reversal. A spring is fixed on the tongue on the battery side to lengthen the contact.

1537. Andrews' Relay, for Hughes' Type Printing Instrument, 1868, used by the United Kingdom Telegraph Company.

This relay is adapted for relaying the short currents required for working the Hughes' instrument; its peculiarity consists in the relayed currents being of equal length, and independent of the length of the line current.

1538. Whitehouse's Relay, 1854.

In this relay a small permanent horseshoe magnet oscillates between the pole pieces of an electro-magnet. The adjustment is effected by the attraction of another small permanent magnet, instead of the spiral spring generally used.

1539. Simple Electro-Magnetic Relay, used by the United Kingdom Telegraph Company.

The simplest form of relay, consisting of an electro-magnet; its armature is attached to one end of a lever, the other end playing between two limiting stops, the local battery circuit being closed when the armature is attracted. A relay similar in principle was used with Bain's Chemical Marking Telegraph on the long lines of the Electric Telegraph Company.

1540. Relays used by the Electric Telegraph Company. Earliest form of relay with an inducing magnet. Superseded by No. 39, 1855.

The coil is wound on a reel of soft iron, upon each end of which a hollow "casing" or cap of the same material is fitted, almost completely

encasing the coil in soft iron. The armature is shaped thus, and is magnetised by induction from a compound bar magnet placed behind. The crescent-shaped portion plays between the inner ends of the casings, which for that purpose do not quite meet, but leave the central portion of the coil exposed.

An ordinary magnetic needle pivoted below the coil is acted upon by the latter, and serves as an indicator to call attention.

The armature is held up against knife-edge bearings by two helical springs, and the adjustment is effected by varying the tension of one of them.

1541. Relays used by the Electric Telegraph Company, 1856. Later form of relay which superseded No. 38 ; a few are still used by the Post Office.

A horizontal bar of soft iron is pivoted vertically, and free to move in the interior of two cylindrical bobbins. The ends of the bar which project beyond the bobbins play between the poles of horsehoe permanent magnets fixed at each end. The relay is adjusted by moving the stops, and consequently the soft iron bar, to one side or the other.

1542. Relay for Bright's Bell Instrument.

A relay or repeater for relaying the signals of the Bright's Bell instrument used on the long lines of the British and Irish Magnetic Telegraph Company, when owing to leakage at the supports, from bad weather or other causes, the direct currents were too weak to work the whole length. In construction it is similar to the relay fixed on the bell instrument itself, but it consists of duplicate bobbins and magnetic needles.

1543. Wheatstone's Type Printing Instrument, 1841.

Steel type punches are fixed at the extremities of separate radiating springs placed round the circumference of a horizontal wheel, which is fixed on the quickest wheel of the train of wheel work, and governed by a dead beat escapement actuated by electro-magnets. The paper band passes under the type, and the printing is performed by an electro-magnet which causes a hammer to strike the proper punch when it is opposite the paper. Alternate layers of white and blackened paper are employed to receive the impressions of the punch.

1544. Theiler's Synchronous Type Printer, 1854.

Two currents are required for each lettter, one to start the instrument and another to print. The type-wheel returns to zero after the printing of each letter, the sending and receiving instruments are made to act in unison, the speed being regulated by a milled nut which is fixed on an arm attached to the anchor of the escapement. Sending and receiving instruments.

1545. Hughes' Type Printing Instrument.

This is a purely synchronous instrument. The instruments at each end of the line are timed to run as nearly as possible at the same speed, and regulated by a spring vibrating in a circle. The type-wheel revolves continually, and does not stop during the printing of a letter. One current only is necessary for the latter operation, which is performed by the wheelwork liberated by an electro-magnet of peculiar construction placed in the line circuit.

Each time a letter is printed the type-wheel if out of time is corrected, that is, moved backwards or forwards on its axis without disturbing the train of wheels, so as to be synchronous with the instrument at the distant station.

1546. Theiler's "Step by Step" Type Printer, 1863–64.

The type-wheel fixed on the axle of the escapement is controlled by reversals, and the printing is performed by the wheelwork, which is brought into action by an electro-magnet, the local battery circuit of the latter being closed by a vibratory arrangement, which does not close the local circuit of this magnet until the type-wheel is stopped at any particular letter.

1547. Dujardin's Type Printer, 1865.

A step-by-step instrument in which the escapement is controlled by reversals, the electro-magnets acting on the anchor of the escapement being worked by a polarised relay in the line circuit, and a local battery.

The operation of printing is performed by an electro-magnet, the local battery circuit of which is closed by the anchor of the escapement at the end of each oscillation.

When the apparatus is running, and no key is depressed, the short currents passing through the printing magnet are insufficient to cause it to attract its armature; but when a key is depressed and the type-wheel stopped at any particular letter the printing magnet attracts its armature, and an impression is made.

An electro-magnetic "cut off" arrangement is used in connexion with the printing magnet, by which the blow struck is always equal in duration whether the key be held down for a longer or shorter time.

The operation of printing is performed at both sending and receiving ends of the line.

This instrument was used for a short period on a wire between London and Edinburgh in 1865, by the Electric Telegraph Company.

1548. Cooke and Wheatstone's Revolving Disc Telegraph, 1840.

A step-by-step instrument. The letters of the alphabet are arranged round a paper disc fixed on the axle of an escapement wheel.

The letters are presented at an opening in the front of the case.

The escapement is similar to the "échappement-à-cheville," and is *controlled* by an electro-magnet.

There are as many teeth in the escapement wheel as there are letters on the revolving disc; the latter moves from one letter to the following for each current sent.

The train of wheelwork is actuated by a mainspring.

1549. Cooke and Wheatstone's Pointer Telegraph Instrument, 1840.

This instrument is similar in all respects to the revolving disc telegraph, excepting that a pointer takes the place of the revolving disc.

1550. Cooke and Wheatstone's Magneto-Electric Communicator, used with their revolving disc or pointer alphabetical telegraph, 1840.

This communicator is so arranged that a current is sent when its spoked wheel is turned through a distance equal to that dividing the letters engraved upon it.

The commutator fixed on the axle of the revolving electro-magnet is so constructed that the magneto-electric currents are all in the same direction.

1551. Bain's Perforator for double dot or Steinheil Alphabet, 1846.

The perforations are made by circular punches on a band of paper, the *right* handle making the perforations on the right hand, and the *left* handle those on the left. The third key on the right is for advancing the paper without punching, for spacing between letters and words.

1552. Bain's Chemical Telegraph. (Incomplete.) First form of recording Instrument used in England, 1846.

The chemically-prepared paper is wrapped round the cylinder. An iron style presses on the paper and writes dots and dashes in a spiral line as the cylinder moves endwise while revolving.

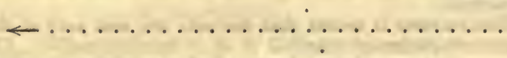
The signals are formed manually by pressing a key, or automatically by a spring, making contact through perforations previously punched in a paper ribbon.

1553. Early form of "Chronopher," or time-current sending apparatus, used in London about 1852. (Incomplete.)

1554. Early form of Wheatstone's Resistance Coils.

1555. Wheatstone's Perforator for punching the paper in the automatic system, 1867.

The right-hand key when depressed perforates the paper thus :—



Which corresponds to a dash in the Morse alphabet.

The left-hand key perforates the paper thus :—

Which corresponds to the dot in that alphabet. The middle key besides being used for spacing, perforates the centre row of holes and moves the paper forward. The centre row of holes acts as a rack in which a star-wheel engages for advancing the ribbon.

1556. Wheatstone's Automatic Transmitter, 1867.

This instrument is used for transmitting automatically the signals punched on the paper ribbon. When no paper is in the instrument reversals are continually sent out to the line by a reversing arrangement actuated by the wheel-work. When the punched paper ribbon is placed in the instrument, it is carried forward uniformly by a star-wheel which engages in the centre row of holes in the ribbon. The reversals are controlled, that is, allowed to pass out to the line or not by the following means:

Two vertical rods or pins are in connexion with the reversing arrangement; these move up and down in readiness to pass through the perforations.

When a marking reversal is sent, the back pin rises and the front one falls.

When a spacing current is sent (that is, the current which moves the marking disc away from the paper at the receiving station) the front pin rises and the back one falls.

When no hole is opposite a rising pin, the current which would have been sent is prevented by the battery being disconnected; thus the lengths of the

signals sent out depend entirely on the interval of time separating two reversals; the back row of holes controls the *marking*, and the front row the *spacing* currents.

A dot is made by a marking current followed immediately by a spacing one.

A dash is made by a marking current followed by a spacing current sent after a longer interval.

For instance, the letter A which is made up of a dot and dash (. ———) is perforated thus:

←

A..C

....

B..D

When the back pin passes through the hole A it allows a marking current to be sent, and the printing disc of the receiver at the distant station is brought against the paper ribbon, but immediately afterwards when the back pin falls the front pin rises through the hole B, allowing a spacing current to be sent, which moves the marking disc away from the paper upon which a dot has been made. The dash is made in a precisely similar way; the back pin rising through the hole C allows a marking current to be sent, and following it at a greater interval than in the case of the dot a spacing current is allowed to be sent by the front pin rising through the hole D, causing a longer mark to be made on the receiving ribbon.

The great difference between this and the earlier systems is, that the contacts are not made *through* the paper, but are *controlled* by the perforations.

The instrument is arranged to send either *intermittent*, *permanent*, or *compensated* currents.

By *intermittent* currents is meant that currents are sent only at the commencement and termination of a signal.

In using *permanent* currents, the latter, whether marking or spacing, are *continuous* for the whole length of the signals, and for the intervals between them, as if a double current Morse key was used.

By *compensated* currents is meant that the latter are continuous, as in the last case, but the first portion only of the currents, whether marking or spacing, is sent of the full strength, as during the remainder of a dash or space a high resistance is inserted automatically between the battery and the line, the current being weakened proportionally.

1557. Wheatstone's Receiver, 1867.

This instrument is used for recording the signals in Wheatstone's automatic system; it is simply a sensitive direct ink writer.

The electrical portion consists of two vertical electro-magnetic bobbins, the iron cores of which are furnished with pole pieces. Two soft iron pieces or tongues are fixed on a vertical axle, and are magnetised by induction from a horseshoe magnet placed near them; they play between the pole pieces of the electro-magnet. The marking disc is in connexion with an arm attached to the vertical axle, and is pressed against or removed from the paper ribbon according as the current passes in one direction or the other through the coils. The tongues of the electro-magnets are set neutral, so that they remain on the one side or the other after the current which has moved them has ceased to act.

The speed of the wheelwork can be regulated at pleasure to suit the rapidity of the signals.

1558. Steinen's Direct Writing Morse Inker, with Morse Signalling Key and Galvanometer.

This instrument is so well known as scarcely to need description, being used in almost every country; its advantage over the Morse embosser consists in the greater legibility of the signals, which can be read in any light, and it requires much less power to work it. This form is used on lines of moderate length, where the direct line current is sufficient to actuate the electro-magnet without the assistance of a relay and local battery.

1558a. Model of a Morse Printing Telegraph (blue writer), with key, galvanometer, and paper stands.

A. Herbst, Berlin.

1559. Siemens' Local Ink-Writer.

Used in connexion with a relay and local battery on lines where the direct current is not sufficiently strong to actuate the direct ink-writer.

1560. Single Needle Instrument.

Used on lines of a class superior to those on which Wheatstone's A B C is employed. It is but little liable to derangement, and requiring no adjustment is preferred to recording or acoustic apparatus for this class of circuit.

It is more trustworthy than the earlier instruments of its kind, on account of the steel magnetic needle inside the coil being superseded by one of soft iron magnetised by induction from a permanent magnet, so that the inconvenience formerly experienced by the needle losing its magnetism is prevented.

A modified construction of Highton's pedal key is adopted instead of the drop handle of the earlier instruments.

1561. Wheatstone's A B C Instrument, Communicator, and Indicator.

This instrument is much used on wires leased to private persons, and for short postal lines, either with or without intermediate stations. It is peculiarly well adapted for these purposes on account of not requiring skilled labour for its manipulation. The instrument being worked by a magno-electric machine within the instrument, batteries are not required.

Switches used with this instrument.

Alarum „ „ „

1562. Double Current Morse Key.

This has superseded the wheel key formerly used It can be arranged either to be worked as a single current Morse key, or to send double currents, as desired.

1563. Stroh's Polarised Relay, with Inducing Magnet.

This relay is similar in construction to the electrical portion of the Wheatstone "Receiver." It consists of two upright electro-magnetic bobbins placed side by side; two horizontal pieces or tongues of soft iron are fixed at their ends on a vertical axle; their other ends play between the pole pieces with which the cores of the bobbins are provided. The adjustment is effected by a spiral spring.

1564. New form of Non-polarised Relay. Post Office pattern.

This consists of two vertical electro-magnetic bobbins the cores of which are prolonged. Two soft iron needles are fixed on a vertical axle passing between the coils, one at the top and one at the bottom end of the axle. These needles are placed crosswise, so that when the cores are rendered magnetic the four poles of the bobbins tend to turn the needles on their vertical axis in the

same direction. Two adjustments are provided, one the ordinary spring adjustment, the other for moving the needles nearer to or further from the poles.

This arrangement is much more sensitive than the old form of non-polarised relay with horseshoe electro-magnet and armature.

1564a. Double-current Key, with levers instead of the ordinary springs.

Series of Apparatus for Recording the Steinheil or Single Needle Code.

The first recording telegraph was Steinheil's, completed in 1837. The code was formed of dots recorded in two lines, those in one of the lines being formed by the +, those in the other line by the − current. The code resembles that of Cooke and Wheatstone's single needle.

The system, if ever brought into practical use, was superseded by that of Morse, in which the code is comprised of marks of varying lengths.

But, as the dash occupies thrice the space and thrice the time of a dot, attempts have been made from time to time to introduce apparatus registering the Steinheil or single needle alphabet.

1564b. Unpolarised Recorder, for registering the single needle code.

1564c. Unpolarised Recorder, for registering the single needle code.

1564d. Polarised Recorder, for registering the single needle code.

1564e. Polarised Recorder, for registering the single needle code.

The negative current prints a *dot* (▪), the positive current *two dots* (:) transversely. The first represents the dot, the second the dash of the Morse alphabet. The letter A is written thus . . . . ▪: .

1564f. Non-polarised Recorder, for registering the single needle code. Richard Herring's system.

The negative current prints a dot (▪), the positive current a transverse dash (|), so that the printing resembles the Morse alphabet. The letter A is written thus ▪ | .

1564g. Modification of Wheatstone's Automatic Transmitter, used in connexion with Richard Herring's system.

1564h. Modification of Wheatstone's Perforator, for his automatic system, arranged to punch the single needle code, used in connexion with Richard Herring's system.

1564i. Specification of John Imray, No. 2,574–1862.

1565. Pony Sounder.

This instrument is of American origin; it is used instead of the ink-writer on some of the lines of the Postal Telegraph Department, the dots and dashes of

the Morse alphabet being read by sound from the clicking of the armature lever instead of from the paper band of the recording instrument; it possesses the advantage of not fatiguing the eye of the operator, and allows him perfect freedom for writing the message.

1566. Double Current Sounder Translator.

This is the usual form of apparatus used for relaying double current Morse signals.

The signals are relayed from the lever of the sounder, the latter being worked by a polarized relay in the line circuit. The necessary alterations to the connexions for restoring the apparatus to its normal condition when transmission in either direction has ceased is accomplished by an automatic switch called a "spacer," which consists of an electro-magnet, armature, lever, and stops. The local circuit of this magnet is closed by the relay which works the sounder when a marking current is sent, and by another relay placed in the line circuit when a spacing current is sent, so that the armature is continually held down while a station is sending.

The armature is prevented from rising during the short interval between the reversals by an electric "shunt," which forms a path for the extra current direct when the local circuit is broken, so that the attraction of the armature is continued.

1567. Duplex Translator for relaying the signals on long circuits, worked on the duplex system.

This apparatus really consists of two sets of duplex instruments, which are combined for the purpose.

1568. Fast Speed Double Current Translator.

Apparatus used for relaying the signals on long wires, worked by Wheatstone's automatic system. The main feature of this arrangement is that the tongue of the relay by which the currents (spacing and marking) are transmitted is set neutral, so that both currents are sent on with the same facility.

This, in addition to the currents being relayed from the tongues direct, without the intervention of sounders, enables the arrangement to work at a much higher speed than previous "translators" or "repeaters."

The tongue is maintained in connexion with either "up" or "down" line wires during transmission by a special piece of apparatus called an "automatic switch," which consists of an electro-magnet, armature, and lever connexions, etc. This electro-magnet is worked by two polarised relays in the line circuit, free to move in opposite directions, so that one of these closes the local circuit of the electro-magnet and keeps it down, any tendency to rise being prevented by the use of an electric "shunt."

When no transmission is taking place the tongues of the relays working the automatic switch fall back into their "rest" stops, and restore the "translator" to its normal condition.

1569. Testing-Box Galvanometer.

Used for testing wires; the requisite changes of connexions for receiving and sending currents are made by a peg switch in front of the instrument.

1570. Regulator Clock and Apparatus for the distribution of Greenwich time current at provincial stations.

The method by which the time signal is distributed may be summarised as follows:—

The wire by which the signal is to be received from the central station, as well as the wires on which the time signal is to be distributed, are connected to he levers of the electro-magnetic switch.

About 20 seconds before 1.0 p.m. a local current sent from the clock actuates this switch, causing the levers to be shifted from the stops which are in connexion with the ordinary instruments, and places them against the opposite stops in connexion with the time relay; the wire from the central station on which the time signal is received being placed in connexion with the coils.

The stop on which this tongue rests is connected to a battery which sends a negative current called the "preliminary," the object of this current being to prevent, as far as possible, stray or contact currents from giving a false signal. It also keeps the tongue of the relay at the distant station on its "rest" stop, and in addition acts the part of a warning signal, which enables the different offices at the proper time to "switch" the line wires into connexion with their respective time relays.

This preliminary current is not supplied from Greenwich Observatory, but is adopted by the Post Office as an additional precaution to ensure the correct transmission of the time signal, and emanates in the first instance from the chronopher at the central station. This preliminary current does not pass beyond the *terminal* office from which the time signal is distributed.

The preliminary current from the central station keeps the tongue of the relay at the clock station on its rest stop until the time-current proper passes through the coils, when the tongue is carried over and placed in connexion with the opposite stop, and through it with the positive pole of another battery, from which at the moment of contact, a current is sent giving the true time signal.

About 20 seconds after the time current has passed, the local current actuating the electro-magnetic switch is interrupted by the clock, and the levers of the switch to which the line wires are attached are by means of a spring again placed in connexion with the stop leading to their respective instruments.

The clock itself is corrected daily in the following way:—

It is kept at a slightly gaining rate, and is stopped automatically by a detent which acts on a pin projecting from the escape-wheel when the hands point to 1.0 p.m. The pendulum, however, continues swinging.

When the time-current is received the outgoing current from the time-relay passes through an electro-magnet inside the clock which liberates the detent, and the clock is set to time.

The clock is so arranged that a second electro-magnetic switch may be actuated, and the time current distributed in a similar way at 10.0 a.m.

1571. Automatic Time-Switch for switching line-wires from their instruments and connecting them to the time-relay.

1572. Time-Relay for relaying and distributing time-currents. (Ordinary Siemens' form.)

1573. Galvanometer for showing incoming time-current.

1574. Galvanometer for showing outgoing time-current.

1575. Lightning Protectors or Dischargers (various).

a. Varley's Lightning Protector (original form).
b. " "
c. " "
d. " "
e. " "
f. " "

g. Varley's Lightning Protector (original form).
h. „ „
i. „ „
k. „ „ Varley's vacuum (modern form). Tube
l. „ „ protector, vacuum tubes in water-tight
m. „ „ compartment for outdoor use.
n. „ „ Latest form of fine wire protector, Post Office pattern, consisting of a metallic bobbin, electro-nickel plated, in connexion with the earth. It is wound with a fine wire covered with silk and passed through melted paraffine wax, the wire being placed in the line circuit. The metallic bobbin is carefully lacquered to secure insulation in damp situations.

1576. Insulators. Various.

Original ring insulator.
Cone insulator, original form (1845).
„ „ later „
„ „ form for repairing broken insulators.
Walker's double-cone insulator (brown).
„ „ „ (white).
Insulator (1847), in which the bolt by which the wire is suspended is insulated by mastic cement in the cavity at the top of the insulator.
Brown earthenware insulator, with zinc cap (1850).
Do., with groove for wire.
Do., glass instead of earthenware.
(1851) brown earthenware.
„ glass.
Clark's invert insulator, corrugated.
Varley's double-cup insulator, fitted.
Ditto, in separate parts, 1862.
Varley's No. 11 wire double-cup insulator.
Brown earthenware insulator called (Z).
Jobson's invert white, double shed.
„ „ single.
South Devon invert insulator (brown).
„ „ „ (white).
Andrews' invert with ebonite inner shed.
„ „ bolt tube „
„ „ bolt tube and shed.
Ebonite insulator, single shed.
Old form of shackle.
Bright's shackle.
Modern terminal insulator.

1576aa. Telegraph Apparatus, &c.
General Direction of Russian Telegraphs.

1. Atlas, containing details of the construction of the Central Telegraphic Office in St. Petersburg.
2. Lightning conductor, for cable.
3. Lightning conductor, for station.
4. Insulator, with double cup (large model), "Korniloff's."
5. Insulator, with double cup (small model), same make.
6. Insulator, with double cup (large model), "Bélotine's."
7. Insulator, with double cup (small model), same make.
8. An element, "Meidinzer's."

1576a. Wheatstone Kaleidophone.
The British Telegraph Manufactory, Limited.

1576b. Wheatstone Kaleidophone.
The British Telegraph Manufactory, Limited.

1576c. Wheatstone's large Dial Indicator, for use with *A B C* instruments.
The British Telegraph Manufactory, Limited.

1576d. Electric Fire Alarum, for warehouses, &c.
The British Telegraph Manufactory, Limited.

1576e. Magnetic Exploder and Fuzes.
The British Telegraph Manufactory, Limited.

1576f. Wheatstone Wave Machine.
The British Telegraph Manufactory, Limited.

1576g. Magnetic Bell, with tell-tale.
The British Telegraph Manufactory, Limited.

1576h. Double Current Key, for Wheatstone's Automatic Telegraph. *The British Telegraph Manufactory, Limited.*

1576i. Double Current Key, for Wheatstone's Automatic Telegraph. *The British Telegraph Manufactory, Limited.*

1576j. Rheostat for Duplex Telegraphing.
The British Telegraph Manufactory, Limited.

1576k. Testing Key.
The British Telegraph Manufactory, Limited.

1576l. Testing Key.
The British Telegraph Manufactory, Limited.

1576m. Testing Key for Discharges.
The British Telegraph Manufactory, Limited.

1576n. Lightning Guard.
The British Telegraph Manufactory, Limited.

1576o. Polarised Relay with Wheatstone's Patent Chain Adjustment.
The British Telegraph Manufactory, Limited.

1576p. Wheatstone Magnetic Counter with Magnet and Wheel showing Mode of Application.
The British Telegraph Manufactory, Limited.

1576q. Magneto-Electric Clock with Steam Engine Movement. *The British Telegraph Manufactory, Limited.*

1576r. Wheatstone's Roman Type Printer for use with the A B C Telegraph.
The British Telegraph Manufactory, Limited.

1576s. Wheatstone's Portable A B C Telegraph, specially arranged for Military Purposes.
The British Telegraph Manufactory, Limited.

1576t. Wheatstone's Alphabetical Magneto-Electric Telegraph. *The British Telegraph Manufactory, Limited.*

1576u. Polarised Morse with Wheatstone's System of Adjustment and Inking.
The British Telegraph Manufactory, Limited.

1576v. Translating Morse with Wheatstone's System of Inking. *The British Telegraph Manufactory, Limited.*

1576w. Resistance Box.
The British Telegraph Manufactory, Limited.

1576x. Resistance Box.
The British Telegraph Manufactory, Limited.

1576y. Large Standard Resistance Box.
The British Telegraph Manufactory, Limited.

1576z. Commutator.
The British Telegraph Manufactory, Limited.

1582. Meidinger's Galvanic Element.
Prof. Dr. Meidinger, Carlsruhe.

1583. Ditto of a larger size.
Prof. Dr. Meidinger, Carlsruhe.

Are for working telegraphs, electric clocks, and bell apparatus, also for electroplating in silver or gold.

1584. Box, containing a battery of 21 elements for producing constant currents for medical use. Entirely new construction of the exhibitors. *Prof. Dr. Meidinger, Carlsruhe.*

The glasses are filled with a solution of bichromate of potash and sulphuric acid in water. The gutta-percha covered rods are introduced into the wide glass, the wires into the mercury tube, with which is connected a platinum wire, leading to the platina sheets. After operation the metal connexions are taken out of the glasses. The liquid is let remain in the glass till it is used out; it may serve for 50 one hour operations. In transport, the liquid does not escape, even in violent shaking. The stoppers with inserted glasses are never taken out. Filling is done by pouring the liquid through the wide tube; emptying by inverting the glass, when the liquid flows out through the fine air passages. The gutta-percha under the zinc is gradually worn away in proportion as the (amalgamated) zinc is dissolved; only about a millimètre of free surface of zinc is necessary. The narrow trough is filled with very dilute zinc vitriol, and serves, through displacement of the zinc pole, in regulation of the strength of current. On drawing out a peg, the liquid escapes below into a central vessel.

1585. Colour-writer (Morse), North German pattern.
L. E. Schwerd, Carlsruhe.

This is furnished with contact-arrangement for translation, and with commutator for sending the current through both electro-magnent coils either successively or simultaneously; in the latter case the resistance of the coils should be only $\frac{1}{4}$.

1586. Box Relay, N. German pattern.
L. E. Schwerd, Carlsruhe.

1587. Key, N. German pattern. *L. E. Schwerd, Carlsruhe.*

1588. Colour-writer (Morse), S. German pattern.
L. E. Schwerd, Carlsruhe.

This apparatus (much used in Baden and Bavaria) is adapted for either constant or working current.

1589. Pendulum Relay, S. German pattern.
L. E. Schwerd, Carlsruhe.

1590. Galvanometer, S. German pattern.
L. E. Schwerd, Carlsruhe.

The deflections of the needle correspond closely between 15° and 35° to the strength of current. The instrument is sensitive and easily portable.

1591. Key, S. German pattern. *L. E. Schwerd, Carlsruhe.*

1591a. Andrew's Guillotine Relay. *W. Andrews, Esq.*

The armature is a permanent horseshoe magnet, placed horizontally, and playing between two electro-magnets, the one above the other below the armature.

The upper electro-magnet is of the ordinary form, the lower one has the cross-piece removed and the poles of a horseshoe permanent magnet connected to its cores instead. The current passes through both coils, which are so connected that the electro-magnets act oppositely upon the permanent horseshoe armature, one attracting while the other repels.

The upper electro-magnet is movable in a vertical direction, and can be shifted up and down by an adjusting screw. This forms the chief adjustment, but a spiral spring is also provided for the purpose.

1607. The Uno-electric Pile with Galvanometer.
Landsberg & Wolpers (*Hanover*).

TELEGRAPHIC APPARATUS CONTRIBUTED BY THE IMPERIAL GERMAN TELEGRAPH DEPARTMENT.

1608. Copy of the Electro-chemical Telegraphic Apparatus of S. T. Sömmering, the first German telegraphic apparatus, constructed in 1809.

1609. Drawing of the Russian Councillor Schilling's (of Kannstadt) **Apparatus,** being the first needle telegraph (two sheets).

1610. Copy of the Electro-magnetic Telegraphic Apparatus of Gauss and Weber, of Göttingen, made and used from 1833 to 1838. Attached to this are—

(*a.*) The signal giver (by means of induced current).

(*b.*) The signal receiver (a magnetic rod with multiplying coil and mirror).

(*c.*) Telescope for reading off the deflexions of the magnet; with stand.

1611. Copy of the Electro-magnetic Telegraphic Apparatus of Steinheil, in München, 1837.

1612. Electro-Magnetic Indicator, combined with a type-printing apparatus of Siemens, of Berlin, constructed in 1846. Patented for Prussia.

1613. Bell Machinery for Railways (Siemens'), 1847.

1614. First Gutta-percha Press for covering conductors with isolating material without a seam. After Siemens' model, and constructed by Fourobert and Bruchner. By machines after this model numerous subterranean lines in Germany and Russia were constructed from 1847 to 1851, and submarine lines are now made in the same manner.

1615. Plate Lightning Conductor, employed first by Siemens in 1848 between Eisenach and Frankfort.

1616. Double Style Apparatus, with writer in relief (Siemens).

Constructed by Siemens in 1853. The lines made by Siemens and Halske, the Warsaw-Petersburg, and other telegraph lines, were at first worked with apparatus of this system.

1617. Polarized Relay for the above. Oldest form without a steel magnet. The magnetic induction of the core and keeper is effected by a branch current of the local battery. (Siemens, 1851.)

1618. Key for the above.

1619. Magneto-electric Current Generator, with 28 pairs of magnets.

1620. Dynamic Mine Exploder (Siemens, 1850).

1621. Polarized Relay for Double-style Apparatus, with steel magnets (Siemens, 1852).

1622. Hand-puncher for Self-acting Sender.

1623. Feeder for above.

1624. Receiver for above (Morse with suspended magnets).

1625. Relay for the above (with suspended magnets).

Employed by Siemens in 1855 in the first experiments made to employ short alternating currents of equal duration for production of Morse writing with aid of a polarised relay.

1626. Mile Resistance, with steel; Siemens, 1854.

1626a. Mile Resistance.

1627. Original Colour-writer of John in Praag, 1854.

1628. Relay with suspended magnets and double coils for conversation. Erichsen and Siemens, 1854. Patented in Prussia, with resistance scale divided according to miles of copper wire, 1''' diameter. As made by Siemens since 1848.

1629. Polarized Relay, with a horse-shoe electro-magnet and steel keeper. Siemens, 1855. This form is still in use.

1630. Induction Coil.

1631. Induction Key.

1632. Apparatus System for submarine conduction. Siemens. Constructed for the Red Sea Telegraph Cable.

1633. Back Current Discharger for submarine conduction. Siemens, 1857. Used first in the Red Sea.

1634. Colour-writer by Siemens. First construction. A little colour arm, fastened on a universal joint, dips in an open reservoir of adjustable level. Patented in England in 1862.

1635. Hair Needle Galvanoscope of Siemens, 1869.

1635a. "Edison's Electric Pen," and "Autographic Press." *Thos. D. Clare.*

This pen consists of a small electro-magnetic engine on the top of a holder, which is used as a pen, and works a needle which pierces the paper, making 5,000 to 6,000 fine holes per minute, so that in writing such is the rapidity of the motion of the needle that the point does not drag or tear the paper.

The pierced paper or "stencil" is placed in a frame, and an inked roller is passed over, which fills the fine perforations with ink. A sheet of paper is then placed below the written paper or stencil, and the roller is again passed over once or twice, when a perfect fac-simile is obtained.

These fac-similes can be produced at the rate of four to six per minute, and one writing or stencil will suffice to print 1,000 copies.

1652. Electric Telegraph, original apparatus as it was made under the direction of its original discoverer, Th. Sömmering, in München, 1809. *K. Sömmering, Frankfort.*

1653. The Volta's Pile, then used for the above, together with the 10 original silver, and 10 original zinc plates.

K. Sömmering, Frankfort.

1654. The Original Conducting Wire, as it was made under the direction of the discoverer in 1809–1811, and tested in the Isar. *K. Sömmering, Frankfort.*

1655. Alarum belonging to Sömmering's Telegraph.
K. Sömmering, Frankfort.

1657. Original Five-Needle Telegraph Dial.
Council of King's College, from Wheatstone Collection of Physical Apparatus.

1658. Two-Needle Telegraph.
Council of King's College, from Wheatstone Collection of Physical Apparatus.

1659. Three A. B. C. Telegraph Sending Instruments, showing gradual improvements.
Council of King's College, London.

1660. Horizontal Sending and Receiving A. B. C. Telegraph Instrument.
Council of King's College, from Wheatstone Collection of Physical Apparatus.

1661. Two A. B. C. Telegraph Receiving Instruments.
Council of King's College, from Wheatstone Collection of Physical Apparatus.

1662. Punching Instrument, for preparing the paper for the transmitter.
Council of King's College, from Wheatstone Collection of Physical Apparatus.

1663. Transmitter.
Council of King's College, from Wheatstone Collection of Physical Apparatus.

1664. First Electric Key, constructed by Sir Charles Wheatstone.
Council of King's College, from Wheatstone Collection of Physical Apparatus.

1665. Wheatstone's First Relay Instrument.
Council of King's College, from Wheatstone Collection of Scientific Apparatus.

1666. Printing Telegraph.
Council of King's College, from Wheatstone Collection of Physical Apparatus.

General Telegraphic Apparatus.

1667. Apparatus specially intended **to illustrate the Morse System of Telegraphy** in primary and secondary schools. *J. Cauderay, Lausanne.*

For the clockwork is substituted a small crank, which can be turned by hand. This apparatus works by means of a single Bunsen cell, of small size. Its low price, 40 frs., including the manipulator, places it within the reach of every school.

1669. Submarine Telegraphic Cables. *Geminiano Zanni.*

In the above specimens the conductor (consisting of one or more copper wires) is enclosed within a series of soft iron wires, which unite to form a strand or core by passing the combined series of wires through a bath of molten tin, or any other comparatively soft metal. The core thus combined into a solid body is protected from corrosion. It is then coated with gutta percha, or any insulating materials, over which tin, or other metal foil, is wrapped to exclude moisture. A band of hemp (immersed in tar) is wound round the core to protect the metal foil from injury or corrosion.

1670. Ward's Dead Beat Telegraph. *William Sykes Ward.*

Two delicate coils of fine wire are suspended on points around the poles of powerful permanent magnets; the motions are limited so as to give distinct indications without tremulous vibrations. Patented in 1847.

1671. Signalling Key for Telegraphy, to send into a line positive or negative currents. *Elliott Brothers.*

1672. Patent Safety Indicator, for the more ready detection of fire. Invented by A. C. Bagot, Esq., of Pembroke College, Cambridge. *Alfred Apps.*

This instrument detects fire instantly on board ships, in ricks, warehouses, &c., gas in coal mines also, and rise or depression of temperature in conservatories, &c.

The invention, as applied to vessels at sea, may be thus described.

There are placed in any one or more compartments, or even intermixed with the cargo, ordinary metallic thermometers and metallic aneroid barometers, a pair of each; in some other portion of the vessel is placed a "Leclanché" or other battery, and in the captain's cabin, or other special locality, there are fixed an electrical indicator and bell, or other alarum.

The pole of the battery is always in direct communication with the indicator and bell. The other pole of the battery is similarly connected with a fixed portion of each of the thermometrical and barometrical instruments at a distance somewhat removed from the sensitive metallic motors of these instruments when in their normal state.

Thus it will be seen that where there is no undue pressure or heat in any one compartment of the vessel, the electric circuit with the battery is incomplete or broken at the points separated by the termination of the conducting wires from the battery and the sensitive metallic motors of the instruments before-mentioned; but in the event of any one or more of the compartments in which the instruments are placed becoming heated or surcharged with gas so as to become subject to an undue pressure, then the sensitive metallic motors of the

instruments would be acted upon, and consequently advance in the direction of the wire communicating with the battery, and so automatically close the electric circuit by making contact with such wire.

Whether such contact be made with the thermometer and aneroid barometer together, or by one singly, the current or circuit is closed and makes *instant* and simultaneous contact with the indicating and alarm apparatus; thus giving instant and positive indication of where danger is developing or assistance required.

1673. Electric Domestic Bells (three). *J. Round.*

1674. Electric Detective Bells (three). *J. Round.*

1675. Apparatus for sending **simultaneously** in opposite directions **Telegraphic Despatches,** between two stations with one single wire in the line.

Elie Wartmann, Professor of Natural Philosophy in the University of Geneva.

A full description is to be found in the number for March 1856 of the "Bibliothèque universelle de Genève." The keys, when worked, close two different circuits, which are to be of such directions and intensities that they neutralise each other in the two sets of coils of the branches of the electro-magnets.

1678. Apparatus for **transmission** of two **simultaneous Telegrams** in the **same Telegraphic Wire,** from one station to another.

Elie Wartmann, Professor of Natural Philosophy in the University of Geneva.

A description of the method and apparatus is printed in the No. for November 1860 of the "Archives des Sciences physiques et naturelles" of Geneva.

1679. Apparatus for permitting any two **Stations** on the same **Telegraphic Wire** to communicate immediately without the aid of the intermediate ones, so that the despatch remains secret between both.

Elie Wartmann, Professor of Natural Philosophy in the University of Geneva.

For complete description see the No. for May 1853 of the "Bibliothèque universelle de Genève." It consists of the following parts:—

a. The *Sender*; *b.* the *Regulator*; *c.* the *Indicator*; *d.* the *Interruptor.* The principles of the instrument are: 1. To break the communication of every intermediate station with the earth; 2. To maintain the contact of their electro-magnets with the poles in order to facilitate the transmission of direct currents between the two stations to be united; 3. To let the officer in the station from which the despatch originates know that it is really received in the proper one; 4. To cut off immediately the communication after the receipt of an answer; 5. To reinforce the current of the battery in the first station by means of the batteries in all intermediate stations.

1676. Electrical Alarum, with Leclanché's battery.

Mariais.

1677. Lamp, with self-registering electrical apparatus, and bichromate of potash battery. *Mariais.*

1680a. First Electro-magnetical Needle Telegraph, invented in the year 1830 by Baron P. L. Schilling (born in 1786 at Reval), consisting of:—

Two electro-magnetical alarum apparatus; two ditto, and gyrotropes (key-board, indicator); one current indicator; one multiplicator for the signs (sign receiver) of the magnetic needle to the right or to the left respectively, turning of the white or black side of a paper disc towards the spectator.

Physical Science Cabinet of the Imperial Academy of Sciences at St. Petersburg.

1683. Cooke and Wheatstone's Single-Needle Instrument. (Early form.) *J. A. Warwick, Esq.*

Used by the Electric Telegraph Company in 1846 on unimportant railway circuits.

The specimen exhibited has a "crutch" handle commutator, but the more general form has the "drop" handle.

1683a. Automatic Lightning Guard.

Warden, Muirhead, and Clark.

1684. Galvanometer of Matteuci.

Royal Institute of "Studii Superiori" at Florence.

1685. Thermo-electric Pile of Nobili.

Royal Institute of "Studii Superiori" at Florence.

1686. Galvanometer of Nobili.

Royal Institute of "Studii Superiori" at Florence.

1687. Original Magneto-electric Machine of Nobili.

Royal Institute of "Studii Superiori" at Florence.

1681. Cooke and Wheatstone's Double-Needle Telegraph, with Alarum. Earliest form, with 6-inch coils and astatic needles. *Reid Brothers, London.*

These instruments were used on the line erected between Paddington and Slough for the purpose of exhibiting the invention.

1682. Double-Needle Instrument. As used by the Electric Telegraph Company in 1846. *Reid Brothers, London.*

Used for all public business, and for the principal railway circuits, with 6-inch coils and astatic needles. The coils were afterwards reduced to one inch. The double needle was superseded for public purposes by the Bain recording instrument from about 1850. It is still used by some railway companies.

1689. Cooke and Wheatstone's A B C Instrument, 1840. *Reid Brothers, London.*

The escapement wheel on the axle of which the pointer is fixed is controlled by electro-magnets.

The communicator is outside, and concentric with the indicator dial, and consists of a cog-wheel working into two smaller wheels. The cog-wheel is turned by a handle, and the battery contacts are made by small wooden cylinders inlaid with metal fixed on the smaller wheels.

The wheelwork is driven by a mainspring.

1690. Nott's Step by Step Pointer Telegraph, 1846. *Reid Brothers, London.*

Electro-magnets act on a ratchet-wheel by means of clicks attached to their armatures. On the axle of the ratchet-wheel the pointer is fixed; the latter is moved forward through a space equal to the distance between two letters for each making and breaking of the battery contact. A simple tapper or pedal key is used for sending the currents, and the pointer is allowed to rest for a short interval when it is opposite to the letter desired to be indicated. The instrument is furnished with an alarum, the bell being struck by a hammer attached to the armature of an electro-magnet provided for the purpose.

1690a. Double Indexed Telegraphic Post, with alphabetical receptor, indicator, and printer at will; manipulator (Chambrier's system) in every direction. *M. Deschiens, Paris.*

The whole of this apparatus is enclosed in a case for protection.

1691. Pocket Telegraph Instrument and Writing Apparatus, arranged for reversing. *Siemens and Halske, Berlin.*

1692. Magnetic Telegraphic Apparatus, with printer. *Siemens and Halske, Berlin.*

1693. Pocket Printing Apparatus, with feeder. *Siemens and Halske, Berlin.*

1694. Quick Composer, with printer. *Siemens and Halske, Berlin.*

1694a. Printing Telegraph, invented by M. H. Jacobi, academician, in the year 1850. Two uniform apparatus for two stations.

Physical Science Cabinet of the Imperial Academy of Sciences at St. Petersburg.

1695. Apparatus for making contact to show the height of water with float, rod-chain, counterpoise, and water tube. *C. & E. Fein, Stuttgart.*

This is self-acting, and registers at any distance off the water-level in a reservoir, &c.

It consists of five parts :—

(1.) The float with chain and counter-weight which when acted on by the rise or fall of the water impart their motion to the contact arrangement.

(2.) The contact arrangement which communicates the motion of the float to the recording instrument by opening or closing the circuit.

(3.) The recording instrument; this shows the level of the water at all times, the pointer being acted on by the motion to and fro of two electro-magnets.

(4.) The conducting wire.

(5.) The battery.

1695a. Model of Aerial Telegraph, by Chappe. *Telegraphs Department, Paris.*

1695b. Model of Aerial Telegraph, by Monge. *Telegraphs Department, Paris.*

1695c. Model of Aerial Telegraph, by Bréguet and Bettancourt. (This model belongs to the Conservatoire des Arts et Métiers.) *Telegraphs Department, Paris.*

1695d. Model of the First French Electric Telegraph, with two needles. *Telegraphs Department, Paris.*

1695e. Electric Telegraph, by Morse, with latest improvements. *Telegraphs Department, Paris.*

1695f. Autographic Apparatus, by Mayer, constructed by Mr. Hardy. *Telegraphs Department, Paris.*

1695g. Quadruple Autographic Apparatus, by Mayer. *Telegraphs Department, Paris.*

1696. Group of Apparatus, consisting of a clock movement for showing the height of water; an electric alarum for indicating the heating of axle bearings by friction. *C. & E. Fein, Stuttgart.*

This is intended to show the heating of an axle in its bearings, and for this purpose is placed in an opening in the cap piece, so that its lower end touches the axle. As soon as the temperature rises, contact is made and a bell rings. The metal of the bearings, plummer block, &c. serve instead of return wires, so that only one insulated conductor is required.

1697. Group of Apparatus, comprising an electric control clock, with six locking signal studs. *C. & E. Fein, Stuttgart.*

This is for use in manufactories, public buildings, &c. The dial is a paper disc, which is changed daily, and revolves once in 12 hours; it contains as many rings as there are stations. By pressing down a knob at any of the stations an electro-magnet inside the clock draws its anchor forward, and a mark is made on the dial. As the dial is very large, minutes can be read off easily. When a new dial is put on, the knob in the centre is to be turned so as to set the clock to the right time. The clock will go for several days, but it is better to wind it up daily. The signalling knobs can be kept locked up, and may be opened by the watchman with a key which is common to the whole apparatus.

1698. Battery Case, containing six large Meidinger's cells for working the above apparatus. *C. & E. Fein, Stuttgart.*

1699. Lamp with Double Screen, slide and adjustable lens, scale stand, scale, &c. To be used with reflecting galvanometers generally. *Elliott Brothers.*

1700. Magneto-electric Railway Block and Day and Night Signalling Apparatus. *Geminiano Zanni.*

1701. Magneto-electric Morse Ink Printing Telegraphic Apparatus. *Geminiano Zanni.*

1702. Magnetic Bells and Signals. *Geminiano Zanni.*

In the above the mechanical electric bell moved by clockwork, at present in use, is dispensed with. The motion of the coils is caused by moving a bell-pull lever half a revolution. Self-acting apparatus may, by this invention, be arranged for giving alarm in case of fire or burglary; by adopting clockwork to set the coil in motion, the bell or signal would act on opening a door or window, or by the heat resulting from fire.

1702a. Electrical Alarum with Leclanché's Battery. *Mariais, Paris.*

This apparatus consists of a watch placed on a box which contains an electrical bell worked by two elements of a chloride of ammonium (called Leclanché's battery). The wire from the zinc is fixed in the binding screw No. 2, the wire from the carbon in the binding screw No. 1. When the small hand of the watch touches the piece which turns in the circular groove, the bell rings until the hand is released by turning the small handle which is at the side of the piece. The binding screw No. 3 which is above is to be used for the wire from the carbon when the apparatus is used as an ordinary electric bell. The polished stem which carries No. 4 binding screw can only be used for six hours, when the rod which carries the platinum point is clamped in the hole.

1702b. Lamp with Self-lighting Electrical Apparatus and Bichromate of Potash Battery. *Mariais, Paris.*

The battery inside is charged with bichromate of potash mixed with about one-tenth water. The lamp, the small tube of which can be seen, is an ordinary benzolin lamp with sponge; when once filled it is put in its place. By pressing on the central button the lamp is made by the mechanism of the apparatus to approach the platinum lighter (inflamateur), which is in the centre. On letting the button go, the lamp is lighted. The cover of the lamp should be replaced by the hand in order to prevent evaporation.

The box contains eight spare platinum plates.

1703. Pair of Undemagnetizable Coils, designed in 1866. *S. Alfred Varley.*

The magnetic needles inside these coils are made of soft iron rendered magnetic by induction, instead of being made of tempered steel magnetized.

As the needles are magnetic only by virtue of the permanent magnets in their neighbourhood, the influence of powerful currents, induced by lightning, upon them, can only be momentary; consequently the telegraphic circuit is

not liable to be interrupted by the demagnetization of the needles, which so frequently occurs in needle telegraphs of the ordinary construction.

Extract from the Handbook of Telegraphy, by R. E. Culley, Engineer-in-chief of Telegraphs to the Post Office, 5th edition, pages 199, 200 :—

"The greatest improvement which has been made in the needle instrument is the introduction of an induced magnet of soft iron for the needle in place of the permanent steel magnet."

1704. Instrument for sending double-curb signals into submarine cables. *Sir William Thomson.*

This instrument was constructed in 1858, but not completed in time for trial on the transatlantic cable before its failure in the September of that year.

1705. Electro-magnet Relay for reaction produced by the magnetism emanating without regulation. Extremely rapid, and produces a novel double effect, something like the cut of a whip. *M. Guyot d'Arlincourt.*

1706. Relay for Rapid Transmission. *M. Guyot d'Arlincourt.*

Application of this relay for the transmission into the rapid apparatus. In this same apparatus two other relays called whipcuts discharge the line with each emission of the current.

1707. Autographic Apparatus. *M. Guyot d'Arlincourt.*

Employment of the circular vibration of the branches of a diapason for regulating the working of the apparatus. New correcting system for ascertaining at once the isochronous action of two apparatuses that are not regulated perfectly one upon the other.

1708. Dial Printing Telegraph. *M. Guyot d'Arlincourt.*

Printing apparatus with electro-magnet of two planes and two effects; one of the planes at the open ends of the electro-magnet governs the recipient, the other at the heel produces the impression of the letter. When the positive and negative currents are thrown alternately and without interruption, the two planes act together, and the local circuit of impression is open. On the interruption of any current, the plane at the heel acts alone, the two planes are no longer united, and the printing takes place.

1709. Morse Sounder. *Dumoulin Froment.*

1709a. Morse's "Sender and Receiver." *Dumoulin Froment, Paris.*

1709b. Detector of Disorder in Pneumatic Telegraph Tubes. *M. Bontemps, Telegraph Inspector, Paris.*

a. With bell.
b. With differential manometer.

Application to Naval and Military Purposes.

1710. Military Morse Direct Indicator, for Field Service.
S. M. E., Chatham.

1711. Military Morse Field Sounder.
S. M. E., Chatham.

1711a. Military Telegraph.
M. Trouvé, 6, *Rue Thérèse, Paris.*

This apparatus is characterised by the junction into one single object of the three parts which constitute a telegraphic post, viz., the monitor, the manipulator, and the reflector; and also by the smallness of its size, which enables a man to carry it on his back, with its cable, like a soldier's knapsack. To this apparatus are adjoined four time-pieces; the two first are tellers transmitting the despatch by sound. The two others have dials, movable and printed on both sides; the one has letters and figures, the other letters only, with blanks for tracing words, which allows of orders being sent as rapidly as by word of mouth.

Fuzes.

(*a.*) Wire or Low Tension Electricity Fuzes.

1712. Earliest form of Fuze used by the Royal Engineers for the explosion of mines by electricity (first used in removing the wreck of the "Royal George," Spithead, 1839).
F. A. Abel, F.R.S.

1713. Mining Fuze, platinum wire, improved construction by Chemical Department, Woolwich. Wire, ·008 inch in diameter (Abel's electric fuze, No. 1). *F. A. Abel, F.R.S.*

1714. Detonators, platinum wire, Chemical Department, Woolwich. Wire, ·003 inch diameter. *F. A. Abel, F.R.S.*

1715. Detonator (low tension), latest construction, with bridges of platinum-silver or indio-platinum wire (·0014 inch in diameter). *F. A. Abel, F.R.S.*

1716. Statham and Brunton's Fuze, 1854. Composition, sulphide of copper and fulminate of mercury. *F. A. Abel, F.R.S.*

1717. Von Ebner's Fuze, 1867 (earliest fuzes constructed by Von Ebner about 1855). Composition, coke, sulphide of antimony, and chlorate of potash, primed with gunpowder.
F. A. Abel, F.R.S.

1718. Abel's High Tension Fuze, 1858. Composition, subphosphide of copper primed with gunpowder. *F. A. Abel, F.R.S.*

1719. Abel's Fuze for Royal Engineer Service, 1862. Composition, subphosphide of copper, primed with gunpowder.
F. A. Abel, F.R.S.

1720. Submarine Fuze, for instructional purposes only. Composition, blacklead and fulminate; priming, sulphide of antimony and chlorate of potash. *F. A. Abel, F.R.S.*

1721. Beardslee Fuze, 1864. Streak of blacklead between the poles, primed with gunpowder. *F. A. Abel, F.R.S.*

1722. Abel's Land Service Detonator. Composition, phosphide of copper, primed with fulminate of mercury.
F. A. Abel, F.R.S.

1723. Submarine Detonator. Composition, graphite and fulminate of mercury; priming, fulminate. *F. A. Abel, F.R.S.*

1724. Gun Tubes (low tension). Original form, McKinlay. Gunpowder priming. *F. A. Abel, F.R.S.*

1725. Abel's Gun Tube (high tension). Original form. Gunpowder kept damp by chloride of calcium (1857).
F. A. Abel, F.R.S.

1726. Gun Tube (high tension). Service, Abel's. Composition, subphosphide of copper, with tube of gunpowder.
F. A. Abel, F.R.S.

1727. Gun Tube, naval, platinum, silver-wire, ·0014 inch in diameter. Composition, gunpowder and gun-cotton, with tube of gunpowder. *F. A. Abel, F.R.S.*

1728. Series of Specimens illustrating the development of the applications of Electricity to the explosions of mines, guns, &c.

1. Original form of wire fuze.
2. Statham fuze.
3. Platinum wire gun tube and section.
4. Experimental high tension fuze.
5. Abel's electric fuze and section. No. 1.
6. Abel's electric gun tube and section. No. 4.
7. Abel's platinum wire fuze and section. No. 5.
8. Austrian electric fuze (Von Ebner's) and section.
9. Abel's submarine fuze and section. No. 2.

10. Abel's electric detonator (land service) and section. No. 5.
11. Abel's electric detonator (submarine) and section. No. 7.
12. Naval electric gun tube and section.
13. Low tension detonator and section. No. 9.

Glass case and printed labels. *War Office.*

1728a. Electrical Communicator. *Garnham & Co.*

This invention enables a perfect communication to be maintained between guards and drivers, and passengers and guards, by means of electricity. The want of a thorough system of communication between guards and drivers on long trains has long been felt, as it is well known that the guard in the after part of a train cannot at all times hear the driver's whistle. By means of this electrical communication a perfect code of signals can be maintained. In the case of danger passengers can readily give an alarm to the guard, and this passenger signal continues ringing until the guard replaces it, and it therefore indicates the compartment of a train in which the alarm bell was sounded. The apparatus consists of a simple battery with the necessary communicators; it is simple, inexpensive, and not liable to get out of order, and is also readily applied to all existing trains.

1729. Glass Globes for producing Electricity by rubbing with the hand.

Museum of King George III., King's College, London.

The globes are caused to revolve by means of multiplying wheels and a band of rope. The globes may be exhausted when they become luminous; the greatest amount of electricity or "fire" was obtained from them when they were exhausted. In the one with a large brass cap, a small wooden disc could be inserted with threads distributed round its edge; when the globe was excited the threads stood out from the edge of the disc. Constructed about A.D. 1720.

c. Electro-Chemical Applications.

1730. Illustration of the Electrotype Process to the Reproduction of Works of Art.

Messrs. Elkington and Co.

Reproduction of a medal. This is an object composed of two parts only, viz., the obverse and the reverse.

a and *b*. Moulds in gutta percha, &c. of the obverse and the reverse.
c and *d*. Moulds with the copper deposited in them.
e and *f*. Copper deposits removed from the moulds.
g. The two sides or portions of the medal as deposited, soldered together ready for finishing.
h. Electro-deposited copy or reproduction of the medal, gilt or silvered.

Reproduction of a small candlestick:

a. The moulds of the base and two sides of the nozzle in gutta percha, &c.
b. Moulds with the copper deposited in them.

c, *d*, and *f*. Copper deposits of the two sides of the nozzle of the candlestick, and the base removed from the moulds.
g. The same soldered together and fitted.
h. The candlestick silvered and completed.

1730a. Reproduction of the "Strauss" Tankard.
South Kensington Museum.

a. A copy or reproduction complete with fictile ivory body or drum.
b. Mould of the "drum."
c. Cast in fictile ivory.
d. Moulds with the copper deposited in them.
e. Copper deposits removed.
f. The same soldered together to form a metal "drum."
g. Moulds of the handle.
h. Moulds with the copper deposited in them.
i. Copper deposits removed from the moulds.
j. The same soldered together as part of the tankard.
k. A group of the other details of the tankard deposited in copper and removed from the moulds.
l. The tankard as soldered together and fitted with copper "drum," ready for gilding, &c.
m. Completed metal copy of the tankard, silvered and parcel gilt.

1730b. A Group of Ferns, &c., in a basket, as an illustration of the method of coating natural objects, however delicate, with copper, and afterwards silvering or gilding the same.

The objects are first prepared with a metallic surface, then immersed in a solution of sulphate of copper, and afterwards electro-plated with gold or silver.

1730c. Electro Jewellery. *Gustave Trouvé, Paris.*

1731. Batteries used in the Electrotype process.
J. How and Co.

Single-cell battery consists of a glass outer cell furnished with a perforated shelf, with an upright porous vessel containing a zinc rod well amalgamated. The porous cell is charged with dilute sulphuric acid, and the object to be coated attached to the binding screw by a copper wire, and suspended in the outer glass vessel, which is filled with a saturated solution of sulphate of copper, a supply of crystals of this sulphate being placed upon the perforated shelf for the purpose of keeping up the strength of the solution.

Smee's battery consists of a central platinised silver plate for the negative element between two zinc plates, connected together by a clamp. It is charged with dilute sulphuric acid.

1731a. Daniell's Constant Battery. *J. How and Co.*

The outer copper cell forming the negative element; the positive element consists of a rod of zinc placed in a porous cylinder. To charge the battery the porous cell is filled with dilute sulphuric acid and the outer cell with a saturated solution of sulphate of copper, crystals of the sulphate being placed

upon the perforated shelf of the outer cell for the purpose of keeping up the strength of the solution.

1731b. Bunsen's Battery. *J. How and Co.*

This consists of a negative element of carbon contained in a vessel of porous earthenware, which is surrounded by a cylindrical zinc positive element in an outer glazed earthenware cell. It is charged by placing concentrated nitric acid in contact with the carbon, and dilute sulphuric acid in contact with the zinc. The zinc is required to be kept well amalgamated.

1731c. Glass Decomposing Cell. *J. How and Co.*

Consists of a glass vessel fitted with two insulated brass bars, with attached binding screws. A piece of sheet copper is hung upon one of the bars, and the object to be coated on the other. The vessel is nearly filled with a strong solution of sulphate of copper. The zinc pole of a battery (say Daniell's) is connected with the bar to which the mould or object to be coated is attached, and the copper pole to that upon which the sheet copper is suspended. This apparatus will also answer for depositing silver and gold.

1732. First Electrotype Reproduction obtained by M. Jacobi. *Conservatoire des Arts et Métiers.*

1732a. Ten Copper Plates, engraved by the electro-chemical process, the proofs from which are in the accompanying album. *Erhard, Paris.*

A proof, fresh printed from a lithographic stone, or an autograph, or a proof from a copper plate wanting to be renewed, is by this process transferred to a copper plate, and produces in a few moments an engraving en creux as clear as that from the original plate, which is in no wise damaged by the operation. By this process it is possible: 1. To avoid having to preserve stones, at once brittle and cumbersome. 2. To reproduce a worn out plate, and so secure unlimited proofs. 3. To effect, upon the copper plate, correcting not feasible upon the original plate worn out by previous printings.

1732b. An Electrotype Apparatus, with stand, and Poggendorff's silver voltameter. *Prof. Hittorf, Münster.*

The vessels serve in investigating the processes by which the electrolytes in aqueous, alcoholic, &c. solution afford passage to the electric current. They make possible the keeping distinct of the changes occurring in the electrodes, and fully determining them by quantitative chemical analysis. In soluble electrolytes the ions can be certainly determined, and so the primary decompositions distinguished from the secondary. Further, the apparatus shows the ratio of the velocities with which the two ions move in opposite directions. (*See* Poggendorf's Annalen, Bd. 89, 96, 103, and 106.)

XII.—SPECIAL COLLECTIONS OF APPARATUS.

1733. Original Apparatus with which **Faraday** obtained the Magneto-Electric Spark.

The Royal Institution of Great Britain.

A welded ring of soft iron six inches in diameter, $\frac{7}{8}$ of an inch thick, one part covered by a helix A containing about 70 feet of insulated copper wire occupying about nine inches in length upon the ring. The other part covered by a second helix B containing about 60 feet of insulated copper wire. The helices are separated from each other at their extremities by half an inch of the uncovered iron.

The iron ring was converted into a magnet by passing a voltaic current through the helix A. This induced an electric current in the helix B, and a small spark was for a moment seen at the carbon terminals.—Phil. Trans. 1831.

1733a. Siberian Loadstone and Spark Apparatus. This was the loadstone employed by Faraday in his experiments on magneto-electric induction, from which he first obtained the induction spark. (*See* Exp. Researches, vol. II.).

Museum of King George III., King's College.

1734. Faraday's original Apparatus for Magneto-Electric Induction by a permanent magnet.

The Royal Institution of Great Britain.

A paste-board tube is surrounded by a helix C of insulated copper wire. The diameter of the tube allows a cylindrical bar magnet to pass freely into it. The terminal wires of the helix are connected with a galvanometer. On the introduction of a permanent bar magnet into the helix, and on its withdrawal from it, currents of electricity were induced in the helix which caused a deflection of the galvanometer needle.—Phil. Trans. 1831.

1735. Faraday's Rotating Rectangle for illustrating the inductive action of the earth.

The Royal Institution of Great Britain.

The wire rectangle provided with a commutator for collecting the currents was attached to a galvanometer, and rotated in the line of the magnetic meridian, the electric current induced in the rectangle deflecting the galvanometer needle.—Phil. Trans. 1852.

1736. Various Helices, Spirals, &c. used by **Faraday** in his researches on Magneto-Electric Induction, &c.

The Royal Institution of Great Britain.

Phil. Trans. 1831.

1737. Magnet made by **Static Electricity,** with note by Faraday. *The Royal Institution of Great Britain.*

"A magnet made at the London Institution by an electric discharge from 70 square feet of charged surface. Present, Sir H. Davy, Pepys Jordan, Bostock, and Faraday."—Note by Faraday.

1738. Portion of the **Battery used by Sir Humphry Davy** in decomposing the alkalies.

The Royal Institution of Great Britain.

Phil. Trans. 1808.

1739. Diagrams of magnetic Curves, prepared by Faraday.
Mrs. Faraday.

1740. Coils and Helices, used by Faraday in his magneto-electric researches. *Mrs. Faraday.*

1741. Model frequently **used by Faraday** during his researches on the rotation of a ray of polarized light by electricity and magnetism. *Mrs. Faraday.*

1742. Block of Glass pierced by sparks from an induction coil. Presented to Faraday by M. Ruhmkorff, 1861.
Mrs. Faraday.

1742a. Apparatus constructed by **A. de la Rive** for demonstrating the rotatory motion which an electric discharge in rarefied gas performs around a magnet.
De la Rive Collection. The property of Messrs. Soret, Perrot, & Sarasin, Geneva.

This apparatus consists of an electric shell, perforated by a soft iron cylinder, magnetised by placing it on one of the poles of an electro-magnet. The electric discharge is produced between the extremity of the soft iron cylinder, which is insulated by a glass tube, and a metallic ring which encircles the soft iron. As soon as the soft iron is magnetised, the electric discharge begins to revolve around it. Previous to Ruhmkorff's improvements in induction-coils De la Rive made this experiment with the current of the "Armstrong" machine.

1742b. Original Apparatus, by Arago and Matteuci.
Polytechnic School, Paris.

1742c. Apparatus devised by **De la Rive & Sarasin** for demonstrating that the electric discharge in a rarefied gas, turning under the power of a magnet, draws with it in its rotatory motion the gas which tranmits it, and all bodies, sufficiently light, that it meets with in its course.
De la Rive Collection. The property of Messrs. Soret, Perrot, & Sarasin, Geneva.

A bell-glass stands upon a platten, which itself must be placed upon the pole of an electro-magnet. This glass being filled with rarefied gas, the electric discharge is completely effected between the central brass ball, and a ring of the same metal constituting the other electrode. A sail-wheel is adjusted inside this ring, so that its vertical paddles may be upon the direct line from the ball to the ring, whereby the discharge strikes it in revolving under the action of the magnet. It then gives it a rotatory direction as soon as the direction of the magnet is changed.

(*See* Archives des Sciences, vol. 45, p. 387; Philosophical Magazine, vol. 44, p. 149.)

1743. Induction Coil by Bonijol, an old Genevese maker.
De la Rive Collection. The property of Messrs. Soret, Perrot, & Sarasin, Geneva.

Bonijol constructed a great number of electrical apparatus under the direction and with the advice of G. and A. de la Rive.

This coil, in which by means of a single medium sized element of constant power, induced currents of considerable force may be produced, was frequently used by A. de la Rive in his researches.

See "Archives de l'Electricité" by de la Rive, 1841, Vol. 1, p. 280.

1744. "Bréguet" Thermometer, used and referred to by **A. de la Rive** in his works upon the causes of voltaic electricity, and upon the properties of magneto-electric currents.

De la Rive Collection. The property of Messrs. Soret, Perrot, & Sarasin, Geneva.

1745. Photographs of a Special Collection of Instruments used by Volta.

Royal Lombardian Institution of Science and Letters.

1st Plate :

1. Electrophorus, with mastic cake, designed by Volta.
2. Condensing electrometer, the same which Volta made use of to demonstrate metallic electricity.
3. Columnar pocket pile, adopted by Volta to demonstrate his theory at the Institute of Paris, Buonaparte being present.
4. Letter of Volta in the original.
5. Lamp for hydrogen gas, which is ignited by the electrophorus. It has the form of those lamps which Volta diffused so much in Germany.
6. Apparatus which served at the first researches of Volta, being available for collecting and rendering appreciable the smallest quantities of electricity.

2nd Plate :

The same instruments on former scales.

3rd Plate :

Fac-simile of part of a letter of Alexander Volta to Professor Bartletti, dated Como, 15th April 1777.

1746. Galvanic Battery, by **A. de la Rive.** The **Grove Battery** modified, with nitric acid on the exterior. Constructed by the Geneva Association for constructing Scientific Instruments.

De la Rive Collection. The property of Messrs. Soret, Perrot, & Sarasin, Geneva.

The nitric acid is placed in a large glass phial, whence it is unnecessary to let it out. It is of sufficient quantity to serve for a long time without being changed.

The diaphragm containing the acidulated water and the zinc closes perfectly the orifice of the phial ; when the battery is taken to pieces, this diaphragm is replaced by a ground stopper. By this arrangement, the disengagement of nitrous vapour is avoided. This battery may thus safely remain in the experimenting room, close to the apparatus, and is especially fit for working a Ruhmkorff coil. Two elements suffice for a medium sized coil. De la Rive constantly used this apparatus for his researches upon induced currents, and always left it in his laboratory.

1747. Floats, constructed by **Gaspard de la Rive.**

De la Rive Collection. The property of Messrs. Soret, Perrot, & Sarasin, Geneva.

Apparatus intended for the demonstration, in a simple manner, of the "Laws of Ampère" upon the reciprocal action of currents. The conductors can be adapted directly upon a small floating battery.

1748. Apparatus, by **A. de la Rive,** for the derivation and the relative measurement of **Induced Currents.** Used by himself in his studies upon rarefied gases.

De la Rive Collection. The property of Messrs. Soret, Perrot, & Sarasin, Geneva.

Used for diverting into a galvanometer a very small portion of a current of induction. This current passes through a glass trough filled with distilled water, in which are dipped two platinum wires, joined to the galvanometer. The current which was passing through the thin liquid thread placed between the wires is partially diverted into the galvanometer, which thus measures a quantity proportioned to the total intensity of the induced current that may go through the trough.

The deviation of the needle of the galvanometer increases proportionally with the distance between the wires.

This apparatus was often used by De la Rive in his researches respecting the passage of the induced current through rarefied gases.

1748a. Apparatus used by **De la Rive and Sarasin** to demonstrate that **Rarefied Gases,** crossed by inductive discharge, become condensed under the action of magnetism.

De la Rive Collection. The property of Messrs. Soret, Perrot, & Sarasin, Geneva.

The inductive current passing through the tube with two compartments, one of which is placed between the two poles of a powerful electro-magnet, the glass cock is rapidly turned round, thus interrupting the current, and separating the two compartments. These are afterwards brought into communication with a very sensitive manometer, and it is then found that the pressure is a little greater in the one which has been between the two poles of the magnet, and which will also contain the negative electrode.

(*See* Archives des Sciences Physiques et Naturelles; new period, vol. 41, p. 5; and Philosophical Magazine, 4th series, vol. 42, p. 211.)

1748b. Apparatus used by **A. De la Rive** in his Studies upon the **Magnetic Rotatory Polarisation** of **Liquids.** (Made by the Geneva Association for Constructing Scientific Instruments.)

De la Rive Collection. The property of Messrs. Soret, Perrot, & Sarasin, Geneva.

1. The Nicol polariser.
2. Tube for holding liquids, with double wrapper for the heating required for studying the influence of the atmosphere upon the phenomenon.
3. The Analyser, with graduated circle and special register, invented by M. Thury. This consists of two tangent discs in ivory, the one supported by the analysing Nicol, the other by the pinion that helps to turn it, and of a horizontal ruler. A pencil mark made by this ruler on both discs shows the position of the Analyser. Instead of having to read each observation separately, which is inconvenient in experiments made in the dark, the corresponding mark to every observation is simply noted, and afterwards reckoned altogether. (*See* Archives des Sciences Physiques et Naturelles, vol. 38, p. 209.)

1749. Apparatus designed by **Auguste de la Rive,** for the demonstration of the **Electric Theory** of the **Aurora Borealis.**

Made by the Geneva Association for the construction of Scientific Instruments.

De la Rive Collection. The property of Messrs. Soret, Perrot, & Sarasin, Geneva.

A large sphere, made of wood, represents the earth. Two iron cylinders represent the two extremities of the terrestrial magnetic axis. They penetrate into two globes filled with rarefied air, which simulate the higher regions of the polar atmosphere. The electric discharge, which takes place in this rarefied air, following rays all around a point situated in the prolongation of the terrestrial axis, turns about this point, and so turns in a different direction at either pole, when the two cylinders are charged by means of a horse-shoe electro-magnet, in accordance with the observations upon the rotation of the rays of the Aurora Borealis. See "Archives des Sciences physiques et naturelles," 1862, vol. 14, p. 121. Philosophical Magazine, 4th series, vol. 23, p. 346.

1750. Metallic Plates, Watch Case, used by A. de la Rive in his first experiments in galvanic gilding.

Lucien de la Rive, Geneva.

1750a. Telegraphic Instruments.

Messrs. Siemens Brothers.

1. A B C telegraph instrument with finger keys (under glass cover to show working parts).
A magneto-electric instrument not requiring battery; used for house, private, and railway telegraphs.
2. A similar instrument in wooden case.
3. A B C telegraph instrument with handle movement, in round case, not requiring battery; used for house, private, and railway telegraphs.
4. A similar instrument in square case.
5. Standard ink recording telegraph instrument with self-starting and self-stopping arrangement; for terminal stations.
6. A similar instrument arranged for translation.
7. Portable telegraph sounder for military purposes (Major Malcolme pattern), non-polarized.
8. Polarized circular relay with double contact.
9. Bi-polarized circular relay with double contact.
10. Portable condenser of $\frac{1}{2}$ microfarad capacity, with 2 terminals and short circuit peg.
11. Sub-divided condenser of 1, 2, 2, 5, 10, 10, microfarad capacity, with 4 spring pegs and one short circuit peg.
12. Sub-divided condenser of 10, 10, microfarad capacity, with 3 terminals and short circuit pegs.
13. Sub-divided condenser of $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, microfarad capacity, with spring pegs and short circuit peg.
14. Sliding rheostat of 10,000 units resistance.
15. Sliding rheostat of 8,400 units resistance.
16. Sliding rheostat of 1,300 units resistance.
17. Resistance coil of 1,000 ohms.
18. Portable resistance bridge for electrical testing, with 3 pairs of proportional coils, viz., 10, 100, 1,000, 10, 100, 1,000, and a set of 16 coils of the aggregate resistance of 10,000 units. All the coils are of platinum-silver alloy. The apparatus also includes battery key, galvanometer key, and reversing commutator.

19. Plate lightning protector for telegraph stations. The line plate and earth plate are of brass, transversely grooved and mounted on marble slab.

20. Lightning protector for telegraph stations. A fine silk covered wire forms part of the line circuit, and is wound round a grooved copper cylinder which is to be placed in connexion with earth.

21. Tubular lightning protector for telegraph stations. The line tube and earth tube are transversely grooved.

22. Universal galvanometer (portable), which serves for the following purposes :—

1st. Measuring electrical resistances, the instrument being arranged as a bridge :

2nd. For comparing electromotive forces. Professor E. du Bois Reymond's modification of Poggendorff's compensation method being used :

3rd. For measuring the intensity of a current, the instrument being simply used as a sine galvanometer.

The instrument consists of a sensitive galvanometer which can be turned in a horizontal plane, combined with a resistance bridge (the wire of which bridge instead of being straight is stretched round part of a circle). The galvanometer has an astatic needle suspended by a cocoon fibre, and a flat bobbin frame wound with fine wire. The needle swings above a cardboard dial divided in degrees; as, however, when using the instrument the deflection of the needle is never read off, but the needle instead always brought to zero, two ivory limiting pins are placed at about 20 degrees on each side of zero.

The galvanometer is fixed on a graduated slate disc, round which the platinum wire is stretched. Underneath the slate disc three resistance coils of the value of 10, 100, and 1,000 Siemens' units are wound on a hollow wooden block which protrudes at one side; this projection carries terminals for the reception of the leading wires from the battery and unknown resistance. The adoption of three different resistance coils enables the measuring of large, as well as small resistances, with sufficient accuracy.

The whole instrument is mounted on a wooden disc which is supported by three levelling screws, so that it may be turned round its axle. On the same axle a lever is placed which bears at its end an upright arm, carrying a contact roller. This roller is pressed against the platinum wire round the edge of the slate disc by means of a spring acting on the upright arm, and forms the junction between the A and B resistance of a Wheatstone's bridge, which resistances are formed by the platinum wire on either side of the contact roller, one of the three resistance coils forming the third resistance of the bridge.

23. Sine galvanometer (portable). The magnetic needle moves on a steel point within the wire coil, and graduated segment inside a circular brass case which turns in a graduated circle.

24. Sine galvanometer (portable) with 3 coils.

25. Detector galvanometer with oscillating magnet.

26. Differential galvanometer, constructed on the double shunt principle.

27. Sounder telegraph instrument with split armature.

28. Set of ink recording instruments for duplex telegraphy, according to the differential system.

29. Double current Morse key with automatic switch for sending and receiving position, to be used with a single battery.

30. Morse key for testing purposes.

31. Double current Morse key for testing purposes.

32. Double current Morse key for signalling.

33. Discharging key.

34. Magneto induction bell with inductor of 6 magnets, for signalling on railways, mines, inclines, &c. without the use of batteries.

35. Magneto induction bell, similar to the above.
36. Ditto ditto.
37. Magneto inductor of 6 magnets, without bell.
38. Dynamo-electric exploder for low tension (quantity) fuses, used for blasting and torpedo firing purposes.

This apparatus consists of an ordinary Siemens' armature, which is caused, by the turning of a handle, to revolve between the poles of an electro-magnet. The coils of the electro-magnet are in circuit with the wire of the armature, and the residual magnetism of the electro-magnet cores excites at first weak currents, which pass into the electro-magnet coils, increasing the magnetism of the core and inducing still stronger currents in the armature wire, to the limit of magnetic saturation of the iron cores of the electro-magnets.

By the automatic action of the machine this powerful current is sent into the wire or cable leading to the fuse. The fuse is practically either an interruption of the cable circuit or a great increase in its resistance at some point, by the interposition of a badly-conducting substance ; the consequent action is that either an electric spark passes between the interrupted portions of the conductor, or the piece of bad conductor is highly heated, causing ignition of the explosive substance contained in the fuse.

The coils, whether of armature or electro-magnets, of the quantity exploder are wound with wire of large diameter to a total resistance of 8 to 10 units in about 2,000 windings ; electric currents possessing great heating power, but of low intensity, are therefore generated by this machine.

39. Dynamo-electric exploder for high tension fuses, also called spark fuses (intensity).

The construction is similar to the above, but this exploder has its coils, both of the armature and the electro-magnets, wound with fine wire to a total resistance of 2,000 to 2,500 Siemens' units, in about 17,000 windings. Upon causing the armature to revolve, currents are generated of great intensity, and an electrical spark passing between the separated conductors in the fuse inflames the explosive priming.

40. Case of electric cable samples.
41. Ditto ditto.
42. Ditto ditto.

1751. Polar-light Apparatus.

Professor Lemström, Helsingfors, Finland.

Report of a speech of Dr. Lemström on his Polar-light apparatus, and the theory of the Polar-light.

This apparatus serves to prove that the polar light or aurora borealis is an electric current flowing from the higher regions of the atmosphere down to the earth.

A sphere of brass, fixed on a bar of india-rubber or ebonite 0·6 meter long, which is screwed in the board of the cross-shaped foot. A cylinder of india-rubber, 3 meters long, is fixed to the same board at about 0·7 meter from the sphere. From the cylinder comes out a branch with a bow, both of india-rubber. On the bow are fixed 16 Geissler's tubes, wherein the air has a pressure of about 0·5 millimeter. The lower ends of the tubes are pierced by platinum wires, which are directed towards the sphere, whilst at the upper end the platinum wires are, by means of their copper wires, in a metallic union with a button, and also in metallic union with the earth. From underneath the sphere a copper wire, well isolated with india-rubber, leads to the negative

pole of a Holtz' electric machine (a machine of Carré (Paris) was employed with great advantage), of which the positive pole is in metallic connexion with the earth. As soon as the machine is put in movement, the sphere being charged, becomes negative-electric, and at the same time there goes through all the tubes a current of reddish-lilac light, so that they altogether form a shining bow-shaped belt. With an ordinary machine this phenomenon may still be observed when the lower ends of the tubes are at a distance of *two meters* from the sphere. This proves evidently that the electricity flowing out from (or into) the sphere not only traverses the layer of air that is between, but goes also with such power through the tubes that the gas therein becomes glowing by the heat that the electric current produces, as is well known. In order that the electricity might more easily flow out in the air from the sphere, this latter is furnished with points. These points, as well as the metallic union between the upper end of the tubes and the earth, are of no absolute necessity, for the phenomenon may be produced without them, only that then the distance between the sphere and the tube must be considerably reduced.

The described light-phenomenon produced by the apparatus proves clearly that a current of electricity may go through a layer of air of ordinary pressure 760^{mm} without producing the light-phenomenon, but if it meets in its way a space of rarefied air of low pressure (from 0 to 30^{mm} to 40^{mm}) there arises immediately a light-phenomenon, caused by the fact that the current makes the molecules of gas glow.

On the Theory of Polar-Light.

The knowledge we have acquired of the electric state of the earth proves that it is a conducting body, charged with a small quantity of negative electricity, and surrounded by the atmosphere, in general charged with positive electricity. Though this latter might be produced by an influence from the earth, it is still very probable that it proceeds from the process of evaporation, either directly by this phenomenon itself, or by the friction of vapour against particles of air. The atmospheric air possesses a very small conducting power for electricity when dry and of ordinary pressure, but the conducting power increases considerably as soon as the air becomes moist and rarefied. It has been proved by experiments that the conducting power is highest at a pressure between 5^{mm} and 10^{mm}, and goes then 10,000 times beyond the conducting power at a pressure of 760^{mm}. If the rarefaction of the air is carried further than 5^{mm}, the conducting power diminishes again, but very slowly. It is known that in proportion to its elevation over the surface of the earth the air becomes more and more rarefied according to an irrefragable law, which finds its expression in the formula given by Laplace, and that consequently, at a certain elevation the earth is surrounded by a layer of air that has a pressure of only 5^{mm}; the conducting power for electricity in this layer is sufficiently great to allow of its being regarded as a conductor in comparison to the air in lower regions, and even in the highest. The negative electric earth is thus surrounded by a conductor for electricity concentric with it. All the positive electricity that attains the space of rarefied air of about 5^{mm}, or, as it might be called, this conductor of air, submits almost to the same laws as if it were in a real conductor, and must thus set in a restricted manner according to the influence of the electro-negative earth. Part of the electricity, conducted by the vapours, remains on the clouds in the atmosphere and discharges in form of lightning and thunder; another part attains the space of rarefied air or conductor of air, by the fact that the vapour itself, submitting to well-known physical laws, rises to this elevation, and also because electricity, according to its nature, endeavours always to set on something.

The manner in which the electricity divides itself on the two conductors depends on their reciprocal position to each other as well as on their form. The earth might, without a remarkable difference, be considered as a sphere, and likewise the conductor of air, but in their reciprocal position to each other it appears that the space of rarefied air of 5^{mm} approaches much nearer to the earth at the poles than at the equator, principally in consequence of the inequality of the temperature of the air in the two places. If we assume the mean temperature of the air round the equator to be 25°, at the poles −12°, and everywhere on the conductor of air −60°, and we suppose at the same time the air everywhere half saturated with moisture, and that the temperature is reduced in proportion to the elevation, we find, if the above-mentioned formula of Laplace (1*) is applied, that the conductor of air, at the equator, must be at an elevation of 37·47 kilometers, and at the poles but 34·25.

In consequence of this relative position, and if the two conductors are regarded as conducting surfaces, the electric density on them both becomes about 9 per cent. greater at the poles than at the equator, and the power, by which the two electricities endeavour to join again, at least 20 per cent., but probably 30 or 40 per cent. greater, if all the circumstances are considered, at the poles than at the equator. It is in these facts we have to seek the principal cause of the accumulation of electricity at the poles of the earth and of the phenomenon that occurs there, and is called polar-light or aurora borealis.

It is a remarkable fact that the thunderstorms diminish as well in number as in intensity in proportion as we remove from the equator, and that at the 70th degree of latitude they cease completely, after having shown once more in the highest north vestiges of their primitive intensity. In Finnish Lapland, for instance, thunderstorms are very uncommon, but when they occur they are extremely intense, and are almost always accompanied by thunderbolts. This peculiarity has probably its cause in the fact that the region of thunderclouds lowers towards the earth in accordance with the same rule as the before-mentioned conductor of air. The reduced number of thunderstorms is caused by the fact that the very source of electricity in the atmosphere, that is to say, the evaporation, is very much reduced; however, another important cause is here active, namely, the heightened conductive power that the air possesses in consequence of its greater quantity of moisture, whereby the electricity becomes unable to keep itself, beyond a certain latitude, upon the clouds, until it has attained a greater tension, but is conducted down to the earth in form of a slow current, visible in the polar-light.

It results from experience, with a high degree of probability, that the polar-light is an electric phenomenon, for its effects are of the same nature as those of the electric currents. Thus the polar-light causes disturbances in terrestrial magnetism, induces currents in the telegraphic wires, and furnishes a spectrum of nine bands, which coincide, except one, with the spectral lines produced if an electric current goes through a rarefied space of air. Thus there is no doubt that the polar light is caused by an electric current going down from the upper rarefied layers of air to the earth; this current, during its passage through the rarefied air, produces light phenomena that cannot arise in denser layers of air.

The polar-light apparatus now exhibited shows that an electric current flowing out from an isolated body does not produce any light phenomena in

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(1*) $X = 18{\cdot}393$ metres $(1 + 0{\cdot}002837 \text{ Cos. } 2\,\phi)\ \frac{(1 + 0{\cdot}004T + t)}{2}\ l\,\frac{H}{h}$ where X signifies the elevation, ϕ the latitude, T the temperature at the surface of the earth, t at the upper point H, and h the stand of the barometer for the same points, but duly reduced.

air of normal pressure, but as soon as it rises to the rarefied air in the Geissler's tubes, there is directly produced a light phenomenon very like the real polar-light. In the apparatus the upper end of the tubes is in union with the earth; this is by no means necessary, for the light phenomenon is also produced if this union be removed, provided that in such case the tubes be brought a little nearer to the isolated sphere. For the rest, the earth represents here the wide space of rarefied air that we find beyond the limits of the conductor of air, and which serves here as an electric reservoir.

Let us now consider how the polar-light on a large scale is formed in nature. As before said, the earth, and the conductor of air, hold to each other the position above mentioned, and the two electricities, the negative electricity of the earth and the positive electricity of the conductor of air, endeavour with a certain force to unite in a belt around the north pole. The isolating power of the denser air prevents this reunion; but if we assume that the equilibrium is attained, so that the isolating power just cannot be subdued, the reunion will instantly take place as soon as this isolating power is diminished or the electricity on the conductor augmented. The first case, which probably is the most ordinary, happens if a southerly wind carrying a quantity of vapour attains the polar regions; for instance, the belt, where the vapour, in consequence of the cold, is condensed into a fluid form, reduces thereby considerably the isolating power of the air and enables the electric current to flow through it. The same thing would occur if a layer of clouds happened to enter into this belt; the upper end of the cloud would become negatively electric, the lower one positive, and thus the distance between the two conductors would in fact be diminished. The electric current would go from the conductor of air to the cloud, and through this latter to the earth. Similar phenomena are observed in the polar regions, for the upper edges of the clouds are not unfrequently seen shining with a yellowish light stretching considerably upwards, whilst no light is discernible under the cloud because of the air there having attained a density sufficient to prevent the current from producing light.

For special knowledge of the polar-light and its theory, we refer to essays inserted in the Archives des Sciences Phys. et Natur. de Genève, 1875 (Sept. and Oct.), and in January 1876, as well as to two essays published in the years 1869 and 1873, in the same scientific journal, all which articles are more or less the result of observations made in the arctic regions. Besides these we may refer also to the works upon polar-light of the American natural philosopher Loomis, Rep. of Smith's Light, 1865, &c.

SECTION 11.—ASTRONOMY.

WEST GALLERY, GROUND FLOOR, ROOM L., AND THE TERRACE OVERLOOKING THE HORTICULTURAL GARDENS.

I.—INSTRUMENTS FOR DETERMINING THE PLACES AND MOTIONS OF THE HEAVENLY BODIES.

a. ASTROLABES.

1752. Suspension Astrolabium. A very old astronomical instrument made in 1525. *Professor Buys-Ballot, Utrecht.*

1753. Astrolabe, constructed for Sir Francis Drake, prior to his first expedition to the West Indies in 1570.
Royal Naval Museum, Greenwich.

This instrument is said to have been preserved in the Stanhope family till 1783. It was subsequently presented to King William IV., who in 1833 deposited it in Greenwich Hospital.

1754. Astrolabe. Ivory, mounted with gilt ormolu. A figure of the Creator is engraved outside. It still retains the original compass and needle. Nuremburg. Dated 1585.
Rev. J. C. Jackson.

1755. A Persian Astrolabe.
The Royal United Service Institution.

Presented to the United Service Institution, May 1842, by Major-General Sir John May, K.C.B., K.C.H.

1756. Ptolemy's Planisphere or Astrolabe, made in 1601, by Michael Coignet, at Antwerp. (See the works of Gemma Frisius, Metius, Lansberghen, &c.)
H. G. Van de Sande Bakhuysen, Director of the Observatory at Leyden.

1757. Ptolemy's Planisphere or Astrolabe, made in the beginning of the 16th century. (See the works of Gemma Frisius, Metius, Lansberghen, &c.)
H. G. Van de Sande Bakhuysen, Director of the Observatory at Leyden.

1758. Two Astrolabes, with four double sights; belonging to H.H. the Prince of Pless. *Committee of Breslau.*

1759. Astrolabe, with movable sun-dial; belonging to H.H. the Prince of Pless. *Committee of Breslau.*

1760. Arabian Planisphere. *Royal Museum in Cassel.*

A small apparatus, of Arabian origin, remarkable for its great age and comparatively good workmanship. It is in the form of a plate made of brass, 16 c.m. in diameter, provided with means for hanging up, and has a movable alhidada. The front side shows a planisphere, the back various divisions and tables covered everywhere with Arabian characters. On nine transposable and one fixed plate can be shown 19 different planisphere drawings for the same number of polar attitudes.

1761. Combined Planisphere and Astrolabe.
Royal Museum in Cassel.

A very strong plate of brass, 37·5 cm. in diameter, with an arrangement for free suspension. On the one side is a planisphere with web, on the other an astrolabe with double sight. The instrument dates from the 15th or 16th century.

1762. Astronomical Circle, after Gemma Frisius, made in 1572, by Gualtherus Arssenius, grandson of Gemma Frisius.
H. G. Van de Sande Bakhuysen, Director of the Observatory at Leyden.

b. Altazimuth Instruments.

1763. 12-inch Altazimuth. *Messrs. Troughton & Simms*

Circles, 12 inches in diameter, divided into spaces of 5′ arc; by means of the attached microscopes these spaces are further subdivided, one division upon the micrometer = 1″ arc.

1763a. Altazimuth on Small Stand. *L. Casella.*

1763b. Altitude and Azimuth Instrument, made by Dollond with double altitude circles.
W. Watson and Son, London.

The instrument stands on three adjusting foot screws, above which is a telescope and the azimuth circle. The azimuth circle is an arrangement of one circle turning within another, so made that their upper surfaces are in the same plane, and the inner edge of the larger in contact with the outer edge of the smaller. The outer edge of smaller circle is divided to 10 minutes of arc, and on the inner edge of larger circle are divided three derniers; above these is the large conical axis of azimuth circle, from the top of which spring rectangular arms carrying the altitude circles and telescope. The telescope is mounted between two 12-inch circles, the peripheries of which are divided on silver to 10 minutes of arc, each circle has two verniers and is furnished with tangent screw movements. Lamp with graduating aperture.

1764. Comet Seeker, on a stand, with horizontal and vertical motion, constructed by Professor Kaiser.
H. G. von Bakhuysen, Director of the Observatory, Leyden.

The stand possesses the advantage that the eye-piece, which is fitted with a perfect reflecting prism, remains at the same height in all the positions of the telescope, whilst the axis of the eye-piece remains horizontal.

1765. Four-inch Achromatic Telescope, on altazimuth stand, with quick and slow motions, in altitude and azimuth.

John Browning.

1766. Instrument for Easy Determination of Time by Equal Altitudes of Different Stars.

Colonel Zinger, Pulkowa.

This instrument is constructed for easy application of the method developed lately by Colonel Zinger for exact determination of time by equal altitudes of different stars (*see* Viertelgebrschrift des Astronomischen Gesellschaft, 1875). The principal condition is unaltered relation of level to telescope in going over from a star in the east to another in the west by having found its vertical axis. The divided circles serve only for setting the telescope. For using only bright and well determined stars down to the (3 or 4) magnitude, 9 minutes of time will be in the average sufficient to give time with the accuracy of $0 \cdot 1^s$. The eye-piece of the telescope is provided with a micrometer, to enable the observer to get with the same instrument, by approximately equal altitudes of two stars near the meridian, exact determination of latitude.

c. Transit Circles and Quadrants.

1767. Meridian Circle, with object glass of 6″ aperture and 6′ focal length. Circle of 2′ diameter under construction for the Observatory of Strassburg. (Photograph.)

A. Repsold and Sons, Hamburg.

(5.) In this instrument the microscopes are attached to the heads of the cast-iron columns, which also bear the bed-plates. One of the pivots carries an objective (2″ aperture), and the other a plate with a bored hole; this arrangement serves, at the suggestion of Prof. Winnecke, as a collimator for controlling the position of the axis. Perfectly central illumination of the field of view is effected by a small mirror at the back of the objective. The heads of the objective and eye-piece can be changed in the heads of the telescope, and there is an arrangement for Nadir observations, also for reflex star observations with a Nadir distance of 8°–60° by means of a movable mercurial horizon.

1768. Transit Instrument, with azimuth circle, a broken telescope of 3″ aperture. (Photograph.)

A. Repsold and Sons, Hamburg.

When the instrument is inverted, which can be very quickly effected, the level and lamp remain hanging, and the binding-screw need not be loosened. There is a microscope for the eye-piece.

1769. Transit Instrument, with straight telescope of 3·3″ aperture. (Photograph.) *A. Repsold and Sons, Hamburg.*

In inverting it is not necessary to loosen the binding screw, and the level remains in position. A microscope is attached to the eye-piece.

1770. Transit Instrument, without case.

Prof. Dr. C. Bruhns, Leipzig, and August Lingke and Co., Freiberg.

The transit instrument is to be used in determination of time and of polar altitudes.

The iron stand is on three feet, and can be set horizontal by means of two levels at right angles to each other. On the stand is a cradle with two supports to carry the telescope, which is always horizontal. There is an arrangement by which this cradle, together with the telescope, can be inverted. In order that the inversion may be as easy as possible, a spring is fixed below the stand, which comes into play when the telescope is inverted, and carries nearly the whole weight of the cradle and telescope. On one side of the cradle is a revolving pivot, which can be brought down between two screws, and according to the position of these screws can be turned through small angles. This movement in Azimuth enables observations to be made with the instrument, not only in the meridian, but also in a vertical arc through the pole, and the index on the cradle which points to a division on the arc gives the position of the cradle in Azimuth. The graduation is so arranged that the interval between two lines gives about 10′, and can be read accurately up to whole minutes.

On the lower stand there is a boss with screws, and when the pivot of the cradle, which rests between the screws, is raised, and the screws at the same time loosened, the telescope can with ease be set in the prime vertical, and by the graduated scale the accurate position in the prime vertical can be read.

The telescope has an aperture of 73 mm., a focal distance of 80 cm., and two achromatic eye-pieces, with magnifying powers of 60 times and 90 times, also two sun-glasses. The telescope is clamped at half its length, and the clamping apparatus is so arranged that the telescope suffers no pressure. Besides, there is at the middle point of the telescope a support with two screws, in order that the telescope may rest firmly when it is clamped: by this means it has a larger base. In front of the objective is a prism (made by Schröder, of Hamburg, who also supplied the objective) giving total reflexion, and permitting the same aperture as the objective. The prism is fastened by six screws on the hypothenuse surface against a strong spring; this spring is so strong that no turning of the prism can occur while alterations owing to change of temperature may take place. On one side there are also parts against which the prism is held by two strong screws on the opposite side. In the hypothenuse surface of the prism there is a dull spot through which the central illumination of the threads is effected. By a revolving arrangement the illumination can be cut off; this arrangement is particularly simple.

The telescope carries the head of the eye-piece, and as it can have only a horizontal direction, the eye-piece must remain always in the same position. A micrometer is attached to the eye-piece which can turn through 90°; this can be used to determine micrometrically the difference of the zenith distance of stars which have nearly the same north and south zenith distance.

There are garnets in the bed plates of the supports so as to lessen the friction. For turning the telescope there is a ring of gutta-percha. The telescope carries a level, which can remain permanently on it; it is graduated to 1″·43. It has also an altitude arc graduated to 10′ and reading to 1′, by means of a vernier. The Nadir distance can be found by an artificial horizon. One turn of the screw micrometer is = $\frac{1}{100}$th of a revolution, and the pitch of the screw is about $\frac{1}{100}$th of a Paris inch.

By this instrument can be determined—

1. The time in meridian.

2. The time in the prime vertical.
3. When it is turned through 90°, the polar altitude, according to the method of Bessel.
4. The polar altitude, according to Falcot's method, where the difference between the north and south zenith distance is measured by the micrometer screw.

1771. Portable Catoptric Transit Instrument, with a telescope horizontally resting in collars, and revolving only on its own optic axis. Invented and constructed by C. A. Steinheil, sen^r^.

Conservatorium of the Math. and Phys. Collections of Bavaria (Prof. Dr. Seidel).

The construction of this instrument is described by its inventor in *Schumachers Jahrbuch für* 1844 (Stuttgart and Tübingen, published by Cotta), p. 3, *et seq.*

1771a. Reflecting Transit Instrument.

W. Watson and Son, London.

In this the image of the star is received on a mirror, and then viewed by looking down through a small telescope placed in such a position as to be most convenient for observation; the telescope is stationary, but the mirror moves in the plane of the meridian, so can be directed to any point in it, and observations taken without those inconvenient positions of the observer, so often necessary with transits of ordinary construction.

1772. Azimuth Quadrant, constructed by Uletz in 1700.

H. G. Van de Sande Bakhuysen, Director of the Observatory, Leyden.

1773. Astronomical Quadrant, said to have been the property of Napier of Merchiston, the inventor of logarithms.

University of Edinburgh.

The telescopes attached are evidently of much more recent and clumsy workmanship than the instrument itself. They are reported to have been added by a "college baillie" (in the days when the university was under the government of the town council), who fancied that he was thereby enhancing the value of his gift to the university.

1774. Quadrant, by Butterfield, of Paris.

Kew Committee of the Royal Society, Kew Observatory.

A brass quadrant, on a wrought-iron pedestal, carrying a telescope, with object glass $\frac{1}{2}$ in. in diameter, and 2 ft. 3 ins. focal length. The quadrant is divided with a diagonal scale, and is provided with a case for hanging a plumb-line.

1775. Quadrant, formerly belonging to Tycho Brahe.

Royal Museum in Cassel (Director Doctor Pinder).

This instrument is the astronomical quadrant of Tycho Brahe. The altitude quadrant, as well as the azimuth dividing circle, are made of brass;

the first is divided into sixths of a degree, the second into whole degrees, which can be read by a simple pointer, but without verniers. The radius of both circles is 40 cm., and the stand is constructed of cast iron.

1776. Two Quadrants, with double sights, old; property of H. H. Prince Pless, Fürstenstein. *Committee of Breslau.*

1777. A Quadrant, for the observation of the height of the sun, old; property of H. H. Prince Pless, Fürstenstein.
Committee of Breslau.

1777a. Quadrant, by Langlois. *Paris Observatory.*

1778. Pillar Sextant, on stand, with artificial horizon.
John Browning.

These instruments are intended for use in an observatory, or otherwise on land, for the purpose of obtaining accurate time.

1779. A small Semicircle, with double sights, for observing the heights of the sun, old; property of H. H. Prince Pless, Fürstenstein. *Committee of Breslau.*

1780. Model of the Greenwich Transit.

1781. Two 12-inch Astronomical Quadrants, by Bird, employed in the observations of the transit of Venus.
Royal Society.

1782. Prismatic Circle, constructed in 1843, from the design of Professor Kaiser.
H. G. Van de Sande Bakhuyzen, Director of the Observatory at Leyden.

By means of two observations the measurement of the angle can be obtained without any instrumental error, excepting those of division. Angles can be measured from 0° to 170°.

1783. Kaiser's Prismatic Circle, constructed on the same principles as the preceding. The construction of the stand, and of a few details, have been improved in this second model.
H. G. Van de Sande Bakhuyzen, Director of the Observatory at Leyden.

d. Equatorials.

1784. An Equatorial Telescope by Abraham Sharp, an eminent mathematician, mechanist, and astronomer, descended from an ancient family at Little Horton, near Bradford in York-

shire, who was born about 1651. He was put apprentice to a merchant at Manchester, but his genius led him strongly to the study of mathematics, both theoretical and practical. By the consent, therefore, of his master, he quitted business and removed to Liverpool, where he studied mathematics, astronomy, &c., and where for a subsistence he opened a school, and taught writing and accounts, &c. He had not been long at Liverpool when he fell in with a merchant from London, in whose house the astronomer, Mr. Flamsteed, then lodged. Mr. Sharp contracted an intimate friendship with Mr. Flamsteed, by whose interest and recommendation he obtained a more profitable employment in the dockyard at Chatham, where he continued till his friend and patron, knowing his great merit in astronomy and mechanics, called him to his assistance in contriving, adapting, and fitting-up the astronomical apparatus in the Royal Observatory at Greenwich, which had been recently built, about 1676. He was principally employed in the construction of the mural arch, which in 14 months he finished, greatly to the satisfaction of Mr. Flamsteed. According to Mr. Smeaton this was the first good instrument of the kind, and Mr. Sharp the first artist who cut accurate divisions upon astronomical instruments. When it was constructed Mr. Flamsteed was 30, and Mr. Sharp 25 years of age. Mr. Sharp assisted Mr. Flamsteed also in making a catalogue of nearly 3,000 fixed stars, with their longitudes and magnitudes, their right ascensions and polar distances, with the variations of the same while they change their longitude by one degree. Among other indications of great genius, it was stated that Mr. Sharp made most of the tools used by joiners, clockmakers, opticians, and mathematical instrument makers. The telescopes he made use of were all of his own making, and the lenses were ground, figured, and adjusted with his own hands. He died July 18th, 1742, aged 91.

The Council of the Yorkshire Philosophical Society, York.

1785. Eight and a half inch Reflecting Telescope, with parabolized silvered glass mirror. *John Browning.*

Equatorially mounted, with powerful driving clock, battery of improved achromatic eye-pieces, double prism solar eye-piece for observations of the Sun. Position micrometer, and new double image micrometer, with rotating hour circle, to facilitate finding objects without calculations.

1786. Four and a half inch Reflecting Telescope, with parabolized silvered glass mirror, on parallactic stand, for following the heavenly bodies with a single motion. *John Browning.*

This instrument was contrived for educational purposes; the mirrors are warranted to be of such quality as to bear well a power of 500 diameters.

1787. Small Universal Equatorial, formerly belonging to the late Dr. W. H. Wollaston. *H. Wollaston Blake, F.R.S.*

1788. Equatorial, small, capable of carrying a telescope of 3 to $3\frac{1}{2}$ inch aperture with perfect steadiness. *Yeates & Sons.*

1789. Equatorial arrangement of a **Refractor,** of 9″ aperture and 13′ focal length, with micrometer eye-piece. (Photograph.)
A. Repsold and Sons, Hamburg.

The declination circle can be read close to the eye-piece of the telescope; it is illuminated by the lamp which illuminates the threads in the field of view of the telescope. By means of one perpendicular roller beneath the centre of gravity, the pressure of the round axis on the bed-plate is removed. The clockwork is arranged in the head of the cast-iron column of which the first are below the floor.

1790. Orbit-sweeper. Equatorial arrangement of a telescope of 6″ aperture, 8′ focal length, with third axis, 1874. Constructed for the Observatory of Strassburg. (Photograph.)
A. Repsold and Sons Hamburg.

In this equatorial arrangement the head of the declination axis has at right angles to it the socket of a third axis, about which the telescope can be revolved, whilst its optic axis can be inclined to the third axis at an angle of $90° \pm 2°$. By means of this arrangement a heavenly body is easily found with a rapid movement of the instrument, as the third axis is directed to the pole of the projection of its orbit. (See Airy's observations on an "Orbit-sweeper," in the monthly notices of the R. Astron. Soc.) The telescope can also be placed parallel to the third axis at the head of the declination axis, and has then a simple equatorial movement. This instrument is provided with clockwork, and has a changeable polar distance from 0° to 66°.

1791. Model of the Great Melbourne Reflector, completed by Messrs. Grubb & Son in 1868. Scale, $\frac{3}{4}$ inch to a foot ($\frac{1}{16}$). *Howard Grubb, F.R.A.S., Dublin.*

Diameter of great mirror, 48 inches.
Focus, 30 feet 6 inches.
Form, Cassegrainian.
The ventilated tube formed of steel lattice bars.
Quick motion in declination
Slow motion in declination
Slow motion in AR - -
Clamping in declination -
} available from eye end of telescope.

1792. Model of the Great Refracting Telescope, of 27 inches aperture, for the new Imperial Observatory at Vienna, now in course of construction at Mr. Howard Grubb's new Astronomical Works, Rathmines, Dublin. Scale, 1 inch to a foot ($\frac{1}{12}$th).
Howard Grubb, F.R.A.S., Dublin.

In this instrument the reading of all circles, right ascension as well as declination, is accomplished from eye end of great telescope.

Also quick motion in right ascension
" quick motion in declination -
" slow motion in right ascension -
" slow motion in declination -
" clamping in right ascension -
" clamping in declination - -
} All available from eye end of telescope.

The one lamp hanging in end of declination axis illuminates—

Upper right ascension circle.
Declination circle in two opposite sides.
Bright and dark fields of micrometer.
Position circle of micrometer.
Field of 4-inch finder.

A second right ascension circle is available for reading from ground floor (south end), where also is a handle for quick setting, right ascension, and a sidereal clock face. The base of the instrument forms a chamber about 12 feet by $4\frac{1}{2}$ feet, in which is contained the clock.

1793. Photograph of a **Heliometer,** with object glass of 4″ aperture and 5′ focal length. This instrument was used by the Russian expedition for the observation of the transit of Venus, 1874. *A. Repsold and Sons, Hamburg.*

The telescope revolves on the head of the declination axis. The scales on both halves of the objective can be read by one magnifier, of which the micrometer is close to the eye-piece of the telescope, and the same magnifier serves to read the metal thermometer on the head of the objective. The slide bars of the objective move simultaneously on cylindrical surfaces in opposite directions. The position circle can be read and all the movements made close to the eye-piece. The instrument is mounted equatorially with changeable polar distance from 0° to 66°, and is moved by clockwork.

1794. Photograph of an Equatorial Refractor constructed for the Observatory in Düsseldorf. *Carl Bamberg, Berlin.*

c. Eye-pieces.

1795. Eye-piece Shutter for Telescopes. Allowing the aperture to be opened and closed by turning the head of the eye-piece. *Captain J. E. Davis, R.N., F.R.G.S.*

This is effected by fitting the kidney-piece with a fulcrum pin and a lever, the latter passing through the side, which is acted on by the head being turned. It obviates the necessity of the slide or kidney-piece fitted with a protruding pin, the latter frequently breaking the nail, or (with gloves on) not being felt; the pin also often loosens, and drops out.

1796. Eye-piece Heliometer.
C. A. Steinheil, Sons, Munich.

In this instrument the images are formed by means of two rectangular prisms, each of which revolves on an axis giving measurements by a screw micrometer. The prisms reflect at less than 45°, and are placed in parallel lines of light. Thus when the reflecting surfaces form an angle with each other, the pencils of rays do not issue mutually distorted, as in other heliometers, but remain centrical at all angles; also the varying distance of the mirror, and of the plan of the image has no longer an influence on the excellence of the image, which appears without parallax. A small telescope with objective prisms serves as eye-piece; it is placed parallel to the telescope axis. The mutual illumination of the image changes with the distance of the greatest diameter from the field of view, in which the images respectively are movable. Any illumination which is taken away from one image is added to the other; the position-circle gives single minutes.

f. Micrometers.

1797. An assortment of the finest Screw-Micrometers, of almost perfect accuracy, and a small instrument for observation.

Hugo Schröder, Hamburg.

This apparatus serves for the examination of screw micrometers, and the micrometers which are exhibited are shown as examples of the great accuracy and delicacy which can be attained by cutting the screws according to the method invented by Hugo Schröder. A table showing the results of the examination of one of the screws by Dr. Vogel is subjoined.

1798. Position (Screw) Micrometer, constructed for the refractor of the Royal Observatory at Berlin.

Carl Bamberg, Berlin.

1799. Four Micrometers, for Astronomical Telescopes.

F. W. Breithaupt and Son, Cassel.

Micrometer divisions on glass, for different kinds of astronomical observation. The one with circular divisions was used by Prof. Spörer, of Anclam, for the observation of the solar protuberances at Aden during the great solar eclipse.

1800. Electro-magnetic Registering Apparatus.

M. Th. Edelmann, Physico-Mechanical Institute, Munich.

1800a. Stereo-Micrometer. Apparatus used with binocular telescopes, and measuring both angles and distances, for geodetical and astronomical measurements. Both eyes being employed, one measuring, the other observing, position and distance are thus given simultaneously. With stereo-micrometrical photographs of landscapes. *Professor Carl Wenzel Zenger, Prague.*

II.—INSTRUMENTS FOR DETERMINING THE MOLECULAR STRUCTURE OF THE HEAVENLY BODIES.

a. Spectroscopes.

1801. Spectroscope of Donati.

Royal Institute of "Studii Superiori" at Florence.

1802. Amateurs' Star Spectroscope. *John Browning.*

This instrument will show the lines in the spectra of stars of the second magnitude, when used with an object-glass only 3 in. in diameter, by detaching the cylindrical lens. The instrument may be used as a small direct vision spectroscope.

1803. Spectrum Apparatus, for the observation of the spectra of the fixed stars, planets, and nebulæ; arranged after the spectrum apparatus of Boshkamper (belonging to the Observatory of Hamburg). *Hugo Schröder, Hamburg.*

The spectrum apparatus is constructed on the simple principle which has proved so successful at the Observatory of Bothcamp, with the difference, however, that this apparatus is arranged for absolute measurement, and that the one at the Observatory of Hamburg is attached at right angles to the principal axis of the refractor.

1804. Spectrum Apparatus, for observing the **Solar Protuberances** to be attached to the collimator of the spectroscope. *Hugo Schröder, Hamburg.*

This spectrum apparatus, which is in reality a supplement of the first one, can be fastened to the collimator of the other one with great readiness. The object of this apparatus is the observation and measurement of the solar spectrum as well as of the solar protuberances. The principle on which it is constructed differs from that of the former one in that the rays after once passing through the system of prisms do not issue from it in the same direction as they entered, but are bent and scattered in favour of the heavy prisms of flint glass. By means of a rectangular prism of crown glass the rays are compelled to pass through the system a second time, and leave it in a direction parallel to that of their first entrance. By a second prism of crown glass the rays are reflected into the observing tube which is attached to the prism holder. The passage of the spectrum across the field of view, as well as the absolute measurement, is effected by turning the first prism of crown glass by means of the screw micrometer. This apparatus is, on account of its convenient and highly stable construction, particularly to be recommended for observers who have scanty room at their disposition, and yet wish to undertake accurate measurements.

1805. Star Spectroscope, after Dr. H. C. Vogel (described in the Berichte der königlichen sächsischen Gesellschaft der Wissenschaften, December 1873). *H. Heustreu, Kiel.*

This apparatus recommends itself for its simple construction, for its varied application for all kinds of observations, and its reasonable price.

1806. Spectroscope made by Merz in Munich. *Prof. Dr. Winnecke, Strassburg.*

1806a. Parts of a Solar Spectroscope, made by Elliott Brothers, in 1869. *J. Norman Lockyer, F.R.S.*

In this instrument the prisms are brought to minimum deviation by means of a spring, suggested by Mr. G. W. Hemming, and the light is brought back through the prisms by a total reflection prism at the end of the train, on the plan first employed, it is believed, in this instrument, and suggested by the contributor.

1806b. Solar Spectroscope, with diffraction grating or speculum metal, presented to the contributor by Mr. Rutherfurd, of New York. *J. Norman Lockyer, F.R.S.*

1806c. Solar Spectroscope, used since 1868 in observing solar phenomena, made by Browning.

J. Norman Lockyer, F.R.S.

1806d. Slit arrangements for Spectroscopes.

J. Norman Lockyer.

d. Stellar Photometry.

1807. Astronomical Photometer for Extinction. Designed by Professor Thury.

Geneva Association for Constructing Scientific Instruments.

The apparent brightness of a heavenly body seen in the telescope is gradually reduced by the changeable diaphragm placed before the objective, and if necessary by the interposition of one or two dark mirrors placed behind the eye-piece in the square box, which is exposed with the diaphragm. The light is gradually reduced until the body is no longer visible. The aperture of the diaphragm is then shown upon a dial placed under the eye of the observer.

The full description of this apparatus is to be found in the "Archives des "Sciences physiques et naturelles de Genève," 1874.

1808. Zöllner's Astrophotometer, for measuring the light of the heavenly bodies by comparison with that emitted by the brightest portion of the flame of a paraffin lamp.

Earl of Rosse, F.R.S.

It being found that, though the total light emitted by the flame varies with its size, the *intensity* of the brightest part does not, appreciably. Two artificial stars are formed by means of a pin hole, a double concave lens, and a double convex lens, which appear in the field by reflexion from front and back faces of a plate of glass alongside of the image of the real star whose light passes through the plate. The intensity of the artificial star is varied, first by changing the pin hole, and finally by two Nicol's prisms, the colour being first matched with that of the star by means of a third Nicol, with a quartz plate between it and the first of the other two Nicols. The instrument is provided with object glasses of various sizes (and diaphragms) up to $2\frac{3}{4}$ inches, and, if fainter stars are to be examined, can be screwed on to the eye-piece of an equatorial instrument. A second arrangement, like the first, but without the quartz plate arrangement, forms an artificial star from moonlight, for comparison of the light of that body with the artificial star.

896. Photometer, constructed by Schwerd for the Observatory of Pulkowa. *The Imperial Observatory, Pulkowa.*

In agreement with Prof. Argelander and M. Otto Struve, the late Prof. Schwerd of Speyer constructed, in 1863, four photometers of the same size, two for Russia (Pulkowa and Wilna), the third for the Observatory, Bonn, the fourth for his own use. The principle of the construction is that of comparing the light of different stars exhibited in the same field by telescopes of different aperture. The diameter of the diaphragms to be applied before the two object-glasses, and corresponding systems of lenses, for purpose of producing equal light and colour, gives the measure of the relative brightness. The two telescopes, one of 2·3ⁱ aperture and 4 ft. focal length, the other of

1·2^{i} aperture and 2 ft. focal length, are parallactically mounted and moved together by the same clockwork (which has been left behind), so that the images of the two stars keep constantly the same place in the field during observation. Being worked out in all parts with greatest care and on sound optical principles, it can hardly be doubted that this instrument answers perfectly its purpose; but on account of the great number of constants to be determined for it, its use is rather difficult. Until now only two of these instruments have been practically applied, that of Schwerd himself, and the one constructed for Wilna. In both cases the first problem has been the determination of the co-efficient of extinction of light by the atmosphere of the earth.

1809. Astrometer for Reflecting Telescopes, invented by the contributor. *E. B. Knobel, F.R.A.S., F.G.S.*

This instrument has been invented for determining the magnitudes of stars on the principle of limiting apertures. It consists of an equilateral triangular aperture, constructed of two plates, one forming the base and the other the opposite angle of the triangle, connected by a screw shaft of peculiar construction. The upper portion carrying the angle plate, being a *right handed*, and the lower connected to the base plate, a *left handed* screw. The pitch of the upper screw is *twice* that of the lower. By simply turning the milled head at the end of the shaft, the aperture is made smaller or larger within the limits of the triangle inscribed in the telescope tube and zero. The instrument depending on the mathematical principle $\sin 30° = \frac{1}{2}$ the aperture is thus always accurately equilateral, and concentric with the mirror or object glass. The graduated base and the micrometer head give the side of the triangle, whence the aperture is readily obtained.

1810. Astro-Photometer, according to Glan's system.
Schmidt and Haensch, Berlin.

III.—OBJECTS ILLUSTRATING THE HISTORY OF THE TELESCOPE AND ASTRONOMICAL OBSERVATION.

1811. Incomplete Telescope with broken lens of Galileo.
Royal Institute of "Studii Superiori," Florence.

1812. Compass of Galileo.
Royal Institute of "Studii Superiori," Florence.

1813. Magnet of Galileo.
Royal Institute of "Studii Superiori," Florence.

1814. Telescope of Galileo.
Royal Institute of "Studii Superiori," Florence.

1815. Object Glass (broken) of Galileo.
Royal Institute of "Studii Superiori," Florence.

1816. Telescope of Torricelli.
Royal Institute of "Studii Superiori," Florence.

1817. Tube of Torricelli.
Royal Institute of "Studii Superiori," Florence.

1818. Telescope of Divini.
Royal Institute of "Studii Superiori," Florence.

1819. Telescope of Mariani.
Royal Institute of "Studii Superiori," Florence.

1820. Telescope of Campani.
Royal Institute of "Studii Superiori," Florence.

1821. Telescope by Amici.
Royal Institute of "Studii Superiori," Florence.

1822. Lens by Benedetto Bryhens.
Royal Institute of "Studii Superiori," Florence.

1823. "Primo Mobile" of Ignazio Dante.
Royal Institute of "Studii Superiori," Florence.

1824. Quadrant of Cosimo I.
Royal Institute of "Studii Superiori," Florence.

1825. Quadrant of Giusti.
Royal Institute of "Studii Superiori," Florence.

1826. Compass of Antonio Blaichini.
Royal Institute of "Studii Superiori," Florence.

1827. Graphometer of Botti.
Royal Institute of "Studii Superiori," Florence.

1828. Registering Thermometer of Fontani.
Royal Institute of "Studii Superiori," Florence.

1829. Natural Magnet of the Accademia del Cimento.
Royal Institute of "Studii Superiori," Florence.

1830. Volume, Experiments in Natural Science Accademia del Cimento. *Royal Institute of "Studii Superiori," Florence.*

1831. Telescope, by Chr. Huygens. The objective ground and polished by him, and bearing his signature.
Professor Dr. P. L. Rijke, Leyden.

Its focal distance is 3·906 m., and its opening 0·0616 m. The eye-piece is composed of three convex lenses. The lens *a*, the nearest to the objective, and the lens *b*, following it, have a focal distance of 0·105 m., and an opening of 0·04 ; the lens *c* has a focal distance of 0·079 and an opening of 0·038 m. The distance between *a* and *b* is 0·212 m. ; that between *b* and *c* 0·182 m. The eye should be placed at a distance of 0·058 from the lens *c*. The lenses *b* and *c* serve only to rectify the images.

1831a. Telescope, by Dolland.

The telescope is the "Dollond," so often mentioned in Humboldt's account of his travels in America.

The sextant and the universal instruments was taken by Humboldt in all his journeys in Asia and America, and on the former depend nearly all the determinations of position. It contains an inscription to this effect, and in the case may still be found the paper in Humboldt's handwriting with instructions for the engraver.

This instrument, together with No. 805, and No. 1766 form a portion of the Humboldt collection, with which friends in Berlin enriched the new observatory of Strasburg, erected in the year 1873.

1831b. Telescope by Campani.

Royal Museum at Cassel (*Director, Dr. Pinder*).

The tube is wood; it measures, when drawn out, 16 feet. This was bought in Rome by Landgrave *Charles.*

1831c. Universal Instrument and Goniometer, by Robinson. *Prof. Winnecke, Strassburg.*

1831g. Two Telescopes (Achromatic), made by Dollond, about 1765, for the Russian expeditions to observe the transit of Venus in 1769.

The Imperial Academy of Sciences, St. Petersburg.

Object glasses of 3·6″ and 2·8″ aperture, focal length 11·2′ and 8·5′. There are several of each size in possession of the Academy. As they are not designated by numbers or other distinct marks, it cannot exactly be made out which of them has been used by the different observers.

1832. Terrestrial Refractor, made by Van Deyl, at Amsterdam, in the year 1781. *Foundation Teyler at Haarlem.*

1833. The Herschel 7-foot Telescope. The original instrument constructed by Sir W. Herschel.

Royal Astronomical Society.

The tube is 7 inches in diameter and 7 feet long. Both mirrors were finished by Sir W. Herschel's own hands; they are sound and whole, but are much tarnished, and the large mirror was damaged in a fire some years since. The framework of the stand is entire, but the moving screws, cords, &c. are useless in their present condition.

1784a. Newtonian Telescope, belonging to Sir W. Herschel, and used by him while living in Bath. He is said to have discovered the planet Uranus by its means. Focus, 7 feet; diameter of speculum, 6⅛ inch. *Edwin Smith.*

This telescope was purchased at Sir W. Watson's sale, Pulteney Street, Bath, about 1860. It had apparently remained after Sir W. Watson's death for some time in a lumber room of the house, and when purchased by Mr. E. Smith, he discovered in the drawer of the stand a paper of directions for the use of the different eye-pieces, which paper he encloses with this.

Mr. Smith adds that there was a portrait in oil of Sir W. Herschel in one of the rooms of the same house, which was sold at the same time. Dr. Brabant, of Marlborough Buildings in this city, who was a great friend of Sir W. Herschel, has often called on Mr. Smith to see the telescope, and repeatedly declared to him that this was the same instrument by which the planet Uranus had been discovered in 1781. It is supposed to have been made by Sir W. Herschel, while organist in the Octagon Chapel, Bath.

1834. A 10-ft. Newtonian Reflecting Telescope by Sir William Herschel, with $8\frac{1}{2}$ inch large mirror, small plane reflecting mirror, and several eye-pieces of various powers.

Rev. Robert Main, Director of the Radcliffe Observatory, Oxford.

This telescope was made by Sir William Herschel for the Radcliffe Observatory in the year 1812, and was received at the Observatory in April 1813; Sir William himself having come to Oxford to superintend the mounting and the adjustments of the mirror.

The correspondence with Dr. Robertson, who was then Radcliffe Observer, is preserved at the Observatory.

1834a. Eight plans of the Telescope, made in London at the end of the last century, under the direction of Sir William Herschell, for the Royal Observatory at Madrid.

Astronomical Observatory, Madrid.

These plans give an exact idea of all the details of the instrument and mounting.

The speculum was of 2 feet aperture and 25 feet focal length.

This instrument was sent from London in 1801, and set up at Madrid in 1804. Four years afterwards the French converted the observatory into a fort, the telescope was destroyed, the only part remaining being the speculum.

1835. Discs of Optical Glass for Refracting Equatorial:

1 Hard crown.

1 Dense flint. *Chance Brothers & Co.*

1835a. A Series of seven Glass Parabolic Mirrors, from $3\frac{1}{2}$ in. to 15 in. in diameter, from 2 ft. to 10 ft. focus, silvered on the surfaces by Liebeg's process.

John Browning, 63, Strand.

1836. Compound Speculum, of 2 feet aperture.

Earl of Rosse, F.R.S.

This is one of the earlier attempts of the late Earl of Rosse to construct specula of considerable dimensions of the hardest and most reflective quality of speculum metal.

To avoid the difficulty of casting the mirror in one, a cubical block of speculum was sawed into laminæ, and these were laid side by side on a ribbed backing of a zinc-copper alloy of the same coefficient of expansion, whose surface had been previously tinned; the whole was carefully brought up to the melting point of tin, and melted tin applied to unite the whole. Though superior in rigidity to the solid metal speculum afterwards successfully constructed, it was discarded in favour of the latter, owing to the injury to definition through diffraction at the junctions of the laminæ.*

Speculum (experimental), with annulus separate from central portion, constructed for the purpose of attempting to correct spherical aberration by advancing the annulus before it had been shown to be possible to produce a paraboloid figure. Given up in favour of the *solid* speculum for same reason as the last (diffraction).

* N.B.—Another compound speculum of 3-foot aperture is still preserved, but the smaller one is sent, as the weight of the other is considerable.

1836a. Small Hand Speculum Polishing Machine, constructed and used by Sir William Herschel to polish specula of 7 feet focus (6 in. aperture). Smaller machines for smaller specula were made of this construction, and are in part preserved. The polishing machines used to figure and polish large specula (18 in. and 49 in. diameter) for the 20 foot and 40 foot telescopes used at Slough and at the Cape of Good Hope were of the same construction as this instrument and of proportionally larger size.

Prof. A. S. Herschel.

1836b. Brass foot used in place of the lead block to carry the furrowed pitch rubber or polisher revolving with the bed plate of the machine, to whose centre it is fastened down by screws. For the largest sized mirrors these brass plates were used as well as for smaller sizes to replace the lead foundation or bearer of the pitch. *Prof. A. S. Herschel.*

Eye-pieces and Objectives.

1837. Objectives and Eye-pieces of the 17th and 18th centuries, the greater part of which were ground and polished by Christian and Constantine Huygens.

Professor Dr. P. L. Rijke, Leyden.

No. 1.	Objective of	120 ft.	Bearing the signature of Const. Huygens.
No. 2.	„	84 „	
No. 3.	„	85 „	
No. 4.	„	43 „ 7 in.	
No. 5.	„	43 „	
Nos. 6 & 7.	„	34 „ each	
No. 8.	„	34 „	Bearing the name of Chr. Huygens.
No. 9.	„	34 „	Bearing the signature of Chr. Huygens.
No. 10.	„	10 ft. 8 in.	Bearing the name of Chr. Huygens.

No. 11. Bearing the name of Hartsoeker.

No. 12. Objective of 32 ft. Bearing the signature of Marcell.

Nos. 1*a* and *b*.	Eye-pieces of	$7\frac{1}{2}$ and 8	inch, to use with objective No.	1.
No. 2*a*.	„	6	„ „ „ „	2.
No. 5*a*.	„	$4\frac{1}{2}$	„ „ „ „	5.
No. 7*a*.	„	$3\frac{5}{8}$	„ „ „ „	7.
No. 8*a*.	„	3	„ „ „ „	8.
No. 10*a*.	„	2	„ „ „ „	10.

1838. Photograph of the **Lens** by which **Huygens** discovered **Saturn's Ring.** *Professor Buys-Ballot, Utrecht.*

* This lens is stated to be the same by which Christian Huygens made out Saturn to be surrounded by a ring. It bears the inscription "X. 3 FEBR. " ꟾDCLV (Febr. 1655), Admovere oculis distantia sidera nostris."

1840. Metal for a Newtonian Reflector, with several wooden eye-pieces, but without tube or mounting, by Hadley.

Royal Society.

IV.—APPARATUS FOR DETERMINING THE EARTH'S MOTION AND DENSITY, &c.

1841. Apparatus used by Baily in repeating the Cavendish Experiment. *Royal Astronomical Society.*

Of this apparatus several parts were missing, but have been lately restored. The original portions are the long mahogany box with glazed ends for the torsion balance, and upright column in the middle for the suspension wires, and a box containing three small leaden, one brass, and two ivory balls, two brass cylinders, and one leaden lenticular weight. A full description of the apparatus will be found in the Memoirs of the Royal Astronomical Society, Vol. XIV.

1842. Gauss's Pendulum for demonstrating the rotation of the earth, executed in the year 1853 by Dr. Meyerstein.
Geodetic Institute of the Observatory at Göttingen (*Prof. Dr. Schering*).

V.—ASTRONOMICAL CLOCKS AND SUNDIALS.

1843. Astronomical Clock, with Sir G. B. Airy's Barometric Compensation. *E. Dent & Co.*

This clock has been fitted up with a Graham escapement; it is in other respects almost a counterpart of the new standard clock of the Royal Observatory, Greenwich.

It is found that the tendency of a clock is to gain with a high barometer, and lose with a low one. Compensation is effected in this way : there is a lever, one arm of which carries a float resting on the surface of the mercury in the cistern of a barometer tube ; the other arm carries a horse-shoe magnet which faces the opposite poles of two bar magnets fastened to the pendulum bob. When the barometer rises the mercury in the cistern is depressed, so that the arm of the lever carrying the float falls whilst the other arm rises, thus bringing the horse-shoe magnet closer to the bar magnets; when the barometer falls the same action takes place in the opposite direction, thus increasing or diminishing a force acting in the same direction as gravity.

1843a. Three different Forms of Dipleidoscope. *E. Dent and Co.*

1. The simple form consists of two mirrors placed at an angle of about 60°, and in front of them a plain unsilvered glass, the whole combination being mounted, for the sake of conveniently taking observations, in a small cast metal pyramid. The optical arrangement operates in this way. Rays from the sun fall upon the front glass, and part are reflected from it and from an image; but the remaining part pass on, and meeting first one and then the other mirror, are reflected back through the front glass, and form a second image. The instrument is to be placed so that these images shall appear together in the field of view, a minute or two before apparent noon. Then what is seen is this : as the sun advances to the meridian the two images will approach, they will touch, and gradually cover one another (this observation gives the instant of apparent noon) ; they will continue to move on, and will finally leave one another ; and each of the observations of contact, superimposition, and parting contact will be each separately and together available for determining true time. The base-plate which accompanies the instrument, it

is intended should be fastened out of doors, in such a position that its guide bar shall give the right direction to the small metal pyramid.

2. The mural form. This instrument only differs from the preceding in its method of mounting, which secures greater accuracy; and a small telescope is added, for the purpose of obtaining a finer reading of all the observations.

(One of these instruments is mounted upon the balcony outside. Upon looking into the telescope (which must be shifted up or down until the images are seen) the two apparent suns will be visible in the field of view; these will gradually approach as above described, and will be superimposed at the instant of apparent noon.)

3. The universal form. This is mounted upon an axis, which by means of a divided "latitude" scale can be placed parallel to the earth's axis. It has also another scale, divided from three hours before, to three hours after noon, and true time may be obtained at any quarter of an hour within this interval. The instrument is furnished with a compass, but this should not be used where more accurate methods of setting it can be employed.

1843b. An Astronomical Signaller for the purpose of giving notice of the approach of stars, or any required point in R.A. to the meridian. *E. Dent.*

1844. System of Patent Electro-Sympathetic Clocks. *James Ritchie & Son.*

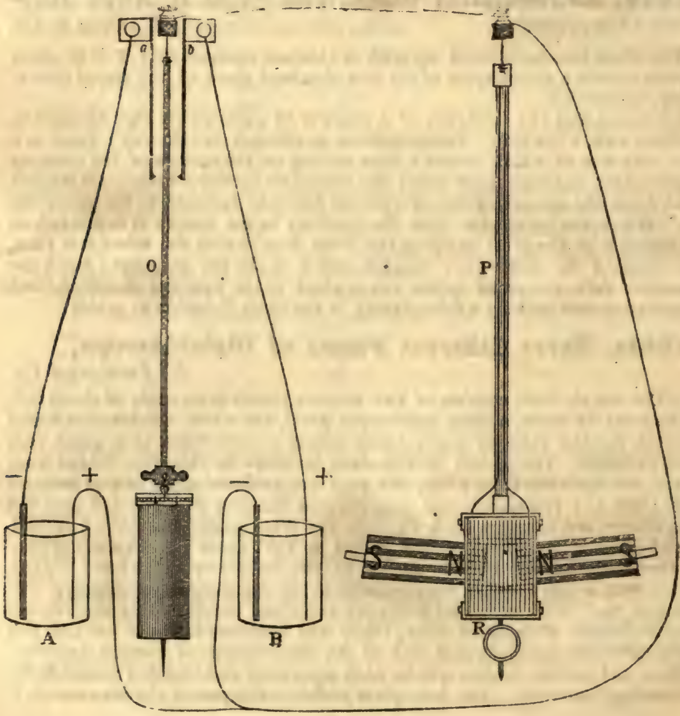

Fig. A.

These consist of—

1st. An ordinary clock, requiring periodical winding, to serve as a normal or motor clock for the system.

Wires from the reverse poles of two galvanic batteries are connected with slender insulated springs, so placed that the pendulum in vibrating touches each alternately, and so transmits through the pendulum rod reverse currents to the line wire and subsidiary clocks.

This arrangement may be seen through the glass sides of the clock-case, and in Fig. A.

2nd. Electro-sympathetic clock. The pendulum consists of a coil of insulated copper wire, the ends of which are led up the rod, and are introduced as a loop into the line wire. Within the coil (which forms the ball or bob) a double cluster of magnets, having their similar poles slightly separated in the middle, is fixed to the casing of the clock. The currents from the motor clock passing through the wire coil cause it to be alternately attracted and

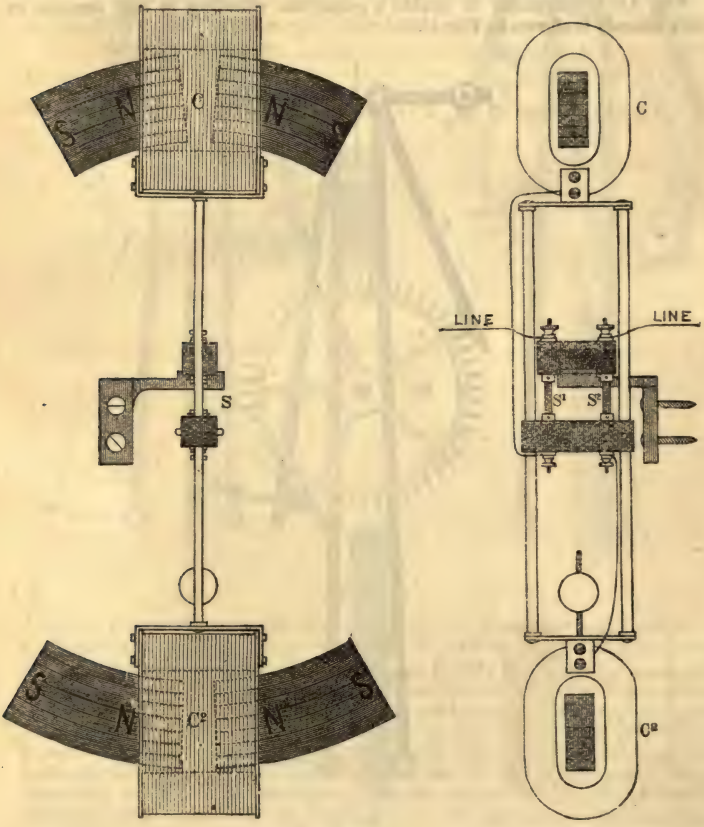

Fig. B.

repelled by the magnets, thereby giving motion to, and maintaining the vibration of, the pendulum. The connexions between the batteries and motor and sympathetic clock pendulums with the position of magnets are shown in Fig. A.

3rd. The sympathetic pendulum is also made with an ordinary ball or bob, carrying a single magnet bar passing into small coils of wire fixed to the case and placed in circuit with motor clock, as shown in the square case.

4th. To admit of a pendulum vibrating in seconds being introduced within the limits of the usual office round clock-case, two small coils, one below and the other above the point of suspension, are used, having double magnets placed for each coil, through both of which the currents from the motor clock are passed.

This form of pendulum requires a more powerful battery to sustain its motion, and has less momentum than the long pendulums. Its construction is shown in the circular case, and in Fig. B.

5th. An arrangement to enable a pendulum vibrating in half seconds to beat seconds is shown in Fig. C.

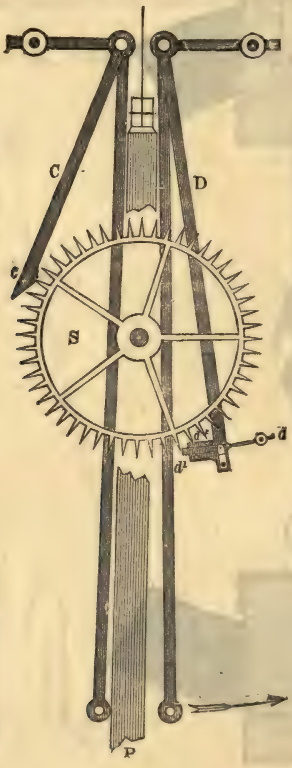

Fig. C.

6th. The wheel-work and hands are propelled by two gravity arms, one on either side of the 'scape wheel, which are alternately raised out of action by the pendulum in its vibration.

The impulse pallets and stops are so adjusted that the wheel is impelled forward half a tooth, and locked upon the opposite arm until released by the return of the pendulum. The action of the propelment is shown in the large-sized movement in the square case, and in Fig. D.

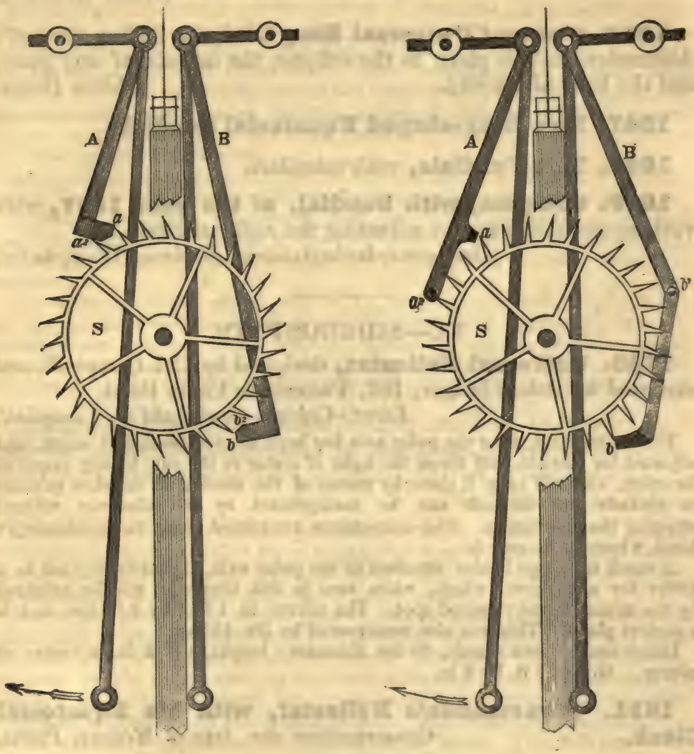

Fig. D.

In this system the standard or motor clock only requires winding, while the sympathetic pendulums, being controlled as well as driven by the electric currents transmitted by the motor clock, are caused to vibrate in unison, and so produce perfect coincidence of time on any number of clocks in connexion though miles distant from it. The electro-motive force being applied at the lower end of the pendulum, a long leverage is obtained requiring only a weak battery, which is less liable to derangement, maintains its constancy and action for a longer time, and requires less attention than a strong one. Each subsidiary clock, being dependent for the time shown upon its own pendulum, is not affected by any trip or irregularity in the current, as the momentum acquired by the pendulum will carry forward the wheel-work for some time

without the current. In other systems, where the current is applied directly to move the wheel-work, a single miss of the current destroys the coincidence of time shown.

1845. Ancient Sundial, for showing the time in any latitude, scale for setting the sun's declination, and equation table.
Elliott Brothers.

1846. Sissons' Universal Ring Dial, for finding the sun's declination and his place in the ecliptic, the latitude of any place, and the hour of the day. *Adam Dixon.*

1847. Two Ring-shaped Equatorial Sundials.

1848. Two Sundials, with calendars.

1849. Compass, with Sundial, of the year 1597, with various movable discs for adjusting the zodiacal circle, &c.
Berggewerkschaftskasse, Bochum, Westphalia.

VI.—SIDEROSTATS.

1850. Universal Heliostat, designed by Col. Campbell, and executed by Adam Hilger, 192, Tottenham Court Road.
Lieut.-Colonel Archibald C. Campbell.

This instrument, after the polar axis has been set due north and south, and adjusted for latitude, will throw the light of a star or the sun in any required direction, and will keep it there by means of the clock; all the slow motions in altitude and azimuth can be manipulated by the observer without stopping the instrument. The connexions are placed ready to the observer's hand, wherever he may be.

A small telescope is also attached to the polar axis, so that it may act as a finder for any object, which, when seen in this telescope, will be reflected by the mirror to the required spot. The mirror is 1 foot by 8 inches, and is a perfect plane. This was also constructed by Mr. Hilger.

Dimensions.—Iron stands, 30 ins. diameter; height, 3 ft. 2 in. to centre of mirror. Mirror, 1 ft. by 8 in.

1851. 'sGravesande's Heliostat, with his Equatorial Clock. *Conservatoire des Arts et Métiers, Paris.*

1851a. Siderostat, by Foucault. *Paris Observatory.*

1851b. Heliostat, by Gamberg. *Paris Observatory.*

1851c. Heliostat, by Silbermann. *M. J. Duboscq, Paris.*

1851d. Heliostat, by Foucault. *M. J. Duboscq, Paris.*

1851e. Photograph of a Siderostat, constructed by Messrs. Cooke and Sons of York, for the Royal Society.
J. Norman Lockyer, F.R.S.

VII.—CELESTIAL PHOTOGRAPHY.

a. Instruments.

1852. The Kew Photo-heliograph, or Telescope, employed at the Kew Observatory for taking photographs of the sun's disc. *Kew Committee of the Royal Society, Kew Observatory.*

A telescope, constructed for the purpose of obtaining photographs of the solar disc. It was constructed, in 1857, by Ross, on the design and under the superintendence of W. De La Rue, Esq., at the cost of the Royal Society; and erected at the Kew Observatory, where occasional sun pictures were taken by its means until 1860, when it was dismounted, and taken to Spain, for the purpose of photographing the solar eclipse of that year. This it accomplished most satisfactorily, and a full account of its work was published in the Philosophical Transactions.

On its return to England, Mr. De La Rue established it at Cranford, where during the year 1861, almost daily, solar photographs were taken with it.

In 1862 it was again removed to Kew, and there maintained in constant operation until 1872. In 1873 it was transferred to the Royal Observatory, Greenwich, where it is now superseded by an instrument of more recent construction.

The diameter of the object glass is $3\frac{4}{10}$ ins., and its focal length 50 ins. An Huygenian eye-piece is employed for magnifying the image, and the instantaneous exposure of the plate is effected by causing a sliding plate, containing an aperture variable at will, to be rapidly drawn across the focus by a strong spring, which is released from the top by cutting a thread.

1852a. Photo-Heliograph, constructed by Dallmeyer, and used for taking **Photographs of the Sun.** This consists of a telescopic camera equatorially mounted, driven by clockwork. *The Astronomer Royal.*

The telescopic camera, total length about 8 feet, is made of brass tubing 5 inches in diameter, parallel for a length of 6 feet, when it opens out into a cone of about 2 feet in length, and sufficiently large at its extremity to receive the camera-screen, or sensitized plate, 6 inches square.

The object glass, of 4 inches aperture and 60 inches focus, corrected for coincidence of chemical and visual foci, occupies the other end of the tube furnished with the means of adjustment for focussing. The sun's image, produced by the object-glass at its focus, measures about half an inch in diameter, when it is enlarged, by a system of lenses termed a secondary magnifier, to 4 inches on the camera screen. The secondary magnifier has all the necessary appliances for adjustment of focus. The difficulty to be surmounted in this arrangement is "optical distortion" in the enlarged image, which is, happily, almost entirely overcome.

Coincident in position with the small sun's image, formed by the object-glass, are perforations in the tube for the admission of sliders, containing apertures with cross-wires, glass reticules, &c. respectively; each capable of being placed concentric with the small image. At the same place also is the instantaneous shutter arrangement for effecting the exposures. This consists of a metal slide, perforated by a slit-opening. The shutter is actuated at one end by a spring, while at the other end a string, passing over a pulley and attached to a hook, can be made to hold the spring in a state of tension. This done, on the thread being cut or burnt, the spring is allowed to act, the shutter flashes across the image forming a cone of rays, exposes the sensitized plate, and the picture is produced. There are provisions for regulating the

exposure by an alteration of the width of opening in the shutter, or by increasing or diminishing the tension of the spring.

The telescopic camera, attached to a bracket by means of two ring-clips or couplings, accurately turned, providing a motion in arc for the camera tube, read off by suitable scale and vernier, is bolted to the end of the declination axis of the—

Equatorial Mounting. This in outline resembles instruments constructed on the German plan, but is "universal," *i.e.*, admits of adjustment for any latitude up to 80°, either North or South of the Equator. A novel contrivance has been introduced for retaining clock gearing for great variations of latitude. Briefly the instrument combines all the most recent appliances for convenience of manipulation, and, though massive as regards construction, it may fairly be called portable. Eleven of these instruments have been sent to various parts of the world, without, it is believed, one single mishap.

1853. Complete Transit of Venus Astronomical Equipment, as used by the English expeditions.

The Astronomer Royal.

1853a. One of the Telescopes used in the "Transit of Venus" Expedition.

The French Commission for Observing the Transit of Venus in 1874.

1853b. One of the Photographic Apparatus used in the "Transit of Venus" Expedition.

The French Commission for Observing the Transit of Venus in 1874.

1853c. Photographic Revolver, used in observing the transit of Venus. *M. Janssen, Member of the Institute, Paris.*

1853d. Photographic Impressions, obtained with the revolver. *M. Janssen, Member of the Institute, Paris.*

1854. Short Focus Mirror, spherical, for telescopes, corrected by two lenses of homogenous media, for reflecting telescopes and astro-photography. With pamphlet.

Professor Carl Wenzel Zenger, Prague.

1855. Aplanatic Object Glass, 4″ aperture, 76″ focal distance, for photographing the heavenly bodies.

C. A. Steinheil, Sons, Munich.

The objective is free from chemical focus, gives perfectly correct and flat images, and is not affected by disturbing reflexions. Each half is achromatic, and consists of two cemented lenses.

1855a. Perfect Diagonal Planes (2), for reflecting telescopes. *Adam Hilger.*

1855b. Right-Angle Prisms (2), for total reflection.

Adam Hilger.

1856. Apparatus for the production of **Photographs of the Sun,** after Dr. Oswald Lohse. *A. Fuess, Berlin.*

1857. Stand with **Equatorial Motion** about a vertical and horizontal axis for a photographic lens of 6″ aperture, used by the German expedition to Kerguelen's Island, for the observation of the transit of Venus, 1874. (Photograph.)

A. Repsold and Sons, Hamburg.

The point of intersection of the horizontal and vertical axis produced is at the same time the centre of movement of the equatorial system, which consists of an hour axis and a declination arc. This arc is suspended from a double arm fastened to one end of the horizontal axis parallel to the telescope, revolving about it, and concentric with the centre of motion. As it is tied to the head of the hour axis, and revolves with it, it compels the double arm, and at the same time the telescope, to move equatorially about the horizontal and vertical axes. By this arrangement the position of a thread in the focus of the object glass can always be controlled by the level attached to the telescope. (See P. A. Hansen, "Beschreibung eines Fernrohrstatio's," &c., in the Berichten der Kgl. sächisch. Ges. d. Wiss. Mathem. Phys. A., 1 Jul. 1870.) To enable the telescope to follow the daily movement there is a screw moved by connexion with the clockwork.

1858. Small Spectrograph. Simple apparatus for taking the sun's spectrum, consisting of a camera (without objective), and a Browning's pocket spectroscope.

Professor H. W. Vogel, Berlin.

The small spectrograph serves for studying the chemical effect of the different parts of the solar spectrum upon substances sensitive to light, and for ascertaining the varying intensities of the various parts of the solar light at different places and times. The slit is wedge-shaped, in order to have more light at one end of the spectrum than at the other. The more intense the chemical effect of a colour, the further it reaches towards the dark end of the spectrum. The apparatus is held in the hand, and so directed upon the sun that the spectroscope may throw no shade. No heliostat is required. The exhibitor has been able to use the instrument on board ship, whilst sailing from Brindisi to Ceylon. (Pogg. Ann., Bd. 156, p. 321.) The exhibited apparatus has been made by *Schmidt* and *Haensch*, Berlin.

1859. Specimen Impression made with the before-mentioned apparatus. *Professor H. W. Vogel, Berlin.*

b. Photographs.

1860. Astronomical Photographs :—

a. The moon, enlarged to 80 and 100 inches diameter by the new re-photographing process.

b. The solar corona and its spectrum, photographed with short foci mirrors and objectives.

c. Solar spots, enlarged 100 times by the "Universal" Microscope, designed by Prof. Zenger, and made by Schieck, of Berlin.

Professor Carl Wenzel Zenger, Prague.

1860a. Photographs of the Arrangement for Obtaining Solar Photographs, by means of Huyghen's lens of 123 feet focal length. *J. Norman Lockyer, F.R.S.*

1861. Photographs of the least refrangible end of the spectrum, by iron and other processes. *Capt. Abney, R.E.*

1862. Daguerreotype of the **Total Eclipse of the Sun** of the 28th of July 1851, taken at the Observatory of Königsberg. *Dr. Schur, Strassburg.*

During the eclipse four photographs were taken. This one was formerly in the possession of Prof. A. C. Petersen, late Director of the Observatory in Altona, and after his death it became the property of his grandson, the exhibitor.

1863. Photographs of the **Sun,** taken with the Kew heliograph, and one of a scale put up for determining the amount of distortion produced by the instrument.
Kew Committee of the Royal Society, Kew Observatory.

The Kew Observatory possesses a set of these negatives, extending from 1858 to 1872, and it is now employed in accurately determining from them the positions and areas of the spots observed during the 10 years 1862–1872, during which they were uninterruptedly obtained.

They are photographed on collodion fibrine, and developed by pyrogallic acid.

The sixth picture in the frame is one of a series of views taken, of a standard scale, suspended to one of the galleries of the Pagoda in the Kew Gardens, distant 1,500 yards, for the purpose of determining the optical distortion of the heliograph.

1863a. Photographic Normal Spectrum of the Sun. Collection of enlarged comparison photographs, used in the research. *J. Norman Lockyer, F.R.S.*

1863b. The Solar Spectrum. Photograph, showing its absorption lines, by George Rutherford, of New York.
Robert James Mann, M.D.

The entire blue part of the spectrum is divided into sections, which are mounted above each other. When these are placed together in their proper continuation, the spectrum is nearly 8 feet long.

1863c. Photographic reproduction of the Solar Spectrum in its natural colours. First proofs obtained by M. E. Becquerel in 1848. (This proof, enclosed in a box, must be protected from the light.) *M. E. Becquerel.*

1864. Photographs of the less refrangible parts of the sun's spectrum, from line E downwards.
Professor H. W. Vogel, Berlin.

(3.) Photograph of a larger spectrograph, which, being in use, could not be spared for this exhibition. The accompanying photographs of the solar

spectrum had been taken on silver chloride and bromide, which had been made sensitive to the less refrangible rays through addition of light-absorbing media.

1864a. Sun spots photographed at Wilna with Dallmeyer's Heliograph. *The Observatory, Wilna.*

These photographs are made with the Dallmeyer heliograph, constructed for the Observatory of Wilna, on the designs of De la Rue. Six of these belong to the period of maximum of sun spots in September 1870, 12 other represent the largest sun spots observed during the years 1871–1875. Similar photographs are made at Wilna every bright day, under the direction of Colonel Smysloff, for promoting the study of the surface of the sun.

1865. Photographs of different parts of the Sun's spectrum.
Dr. H. C. Vogel and Dr. Chr. Lohse, Potsdam.

1866. Photographs of the Sun.
Dr. H. C. Vogel and Dr. Chr. Lohse, Potsdam.

1867. Photographs of Jupiter.
Dr. H. C. Vogel and Dr. Chr. Lahse, Potsdam.

1868. Drawing of the Spectrum of the Sun between Fraunhofer's lines H_1 and H_2, made from a photograph.
Dr. H. C. Vogel and Dr. Chr. Lohse, Potsdam.

1869. Specimens of Photographical Multiplication and **Reversion** of astronomical drawings of nebulæ and comets (Dr. Vogel's method).
Dr. H. C. Vogel and Dr. Chr. Lohse, Potsdam.

1870. Lunar and Solar Photographs. *Warren de la Rue.*

1870a. Enlarged Solar Photographs, by Mr. Rutherford of New York. *J. Norman Lockyer, F.R.S.*

VIII.—CHRONOGRAPHS.

1871. Wheatstone's Magnetic Chronograph, for measuring very small intervals of time.
Wheatstone Collection of Physical Apparatus, King's College.

1872. Groves's Chronograph, for astronomical calculations, for railway speed, and speed of machinery. *W. Groves.*

1873. Yvon Villarceau's Astronomical Chronograph.
Exhibited by Bréguet.

1874. Carrington's Astronomical Chronograph, made by Smith and Beck. *Exhibited by Dr. Stone.*

1875. Electro-magnetic Registering Apparatus.
M. Th. Edelmann, Physico-Mechanical Institute, Munich.

IX.—EDUCATIONAL.

1876. Sphere, moved by clockwork, of the Burgh Institution (1580).

1877. Sphere, moved by clockwork, of Jean Reinhold (1588).

1878. Sphere bearing traces of M. Foucault's observations on the Rotatory motion of the Earth.
Conservatoire des Arts et Métiers, Paris.

1879. Apparatus for demonstrating the **Retrogradation** of the **Superior and Inferior Planets,** also of the **Synodic Revolutions, the Transits of Venus and Mercury, &c.**
J. J. Oppel.

The long wire represents the line of vision, the small shield at one end the apparent position of the planet, the fixed ball at the other end the earth, and the movable ball the planet. The latter is fixed on the pivot of the smaller or larger turn-table, according as it is wished to demonstrate the retrogression of an inferior or superior planet. The twelve signs of the zodiac are hung up on the walls of the lecture room; the handle must be turned to the right; the angular movement of the line of vision to the right demonstrates the retrogression.

1880. Cosmographical Apparatus, to explain various natural phenomena, made by M. Robert, of Paris, and purchased for the South Kensington Museum in the Paris Exhibition of 1867.

1. The seasons.
2. The seasons.
3. Phases of the moon.
4. Eclipses.
5. Librations of the moon.
6. Real and apparent motion of the planets.
7. Fall of bodies.
8. Inequality of the seasons.
9. Precession of the equinoxes, physical.
10. Precession of the equinoxes, geometrical.
11. Precession of the equinoxes, mechanical.
12. Star to indicate a point in space.

1881. Nutoscope. Apparatus showing the laws of precession and nutation, and the conservation of the plane of rotation. With diagrams, constructed by the aid of the apparatus.
Professor Carl Wenzel Zenger, Prague.

1882. Orrery, lighted with gas, for the demonstration of eclipses, and, by the aid of a "sablier," tracing the real orbit of the moon. *Ernest Recordon, Geneva.*

This apparatus shows:

1. By means of a jet of gas behind globes, representing the celestial bodies, a sufficient shadow is cast to give a clear idea of eclipses and the phases of the moon.
2. The orbits of Venus, the Earth, and Mars.
3. The difference in length of planetary years.
4. The diurnal rotation of the Earth.
5. The two classes of planets; the smaller represented by Venus, the greater by Mars.
6. The phases of the moon. Demonstration effected by means of a flame or gas.
7. The real orbit of the moon. By means of a special contrivance, an epicycloidal line of fine sand is traced, which perfectly represents the lunar orbit.

1883. Selenographia, for showing all the effects of libration, rotation, and elongation on the surface of the moon. *John S. Marratt.*

This instrument, the invention of Mr. John Russell, illustrates the various Lunar phenomena, the libration in latitude and polar obliquity, the libration in longitude, the mean state of libration, diurnal and monthly, the periodical and synodical revolutions, and how to determine the position of polar axis, &c.

1884. Planetarium or Orrery, designed by Ch. Huygens, constructed by J. Van Ceulen, set in motion by clockwork. *Professor Dr. P. L. Rijke, Leyden.*

1884a. Planisphere, with glass globe. *A. Herbst, Berlin.*

1885. Model of the Solar System, made by Professor Kaiser for his popular lessons on astronomy. The orbits of the planets from Mercury to Jupiter are represented in their relative dimensions.
H. G. Van de Sande Bakhuysen, Director of the Observatory at Leyden.

1885a. Cosmographic Clock, reproducing all the astronomical phases of our globe, in relation to the sun. *M. Mouret, Paris.*

1887. Model devised by the Rev. **James Bradley,** Savilian Professor of Astronomy, &c., and used by him for illustrating his discovery of **Aberration.** *R. B. Clifton.*

For a description of this model, see Phil. Mag., Dec. 1846, vol. 29, p. 429.

1888. Planetarium, with clockwork. *Ernst Schotte, Berlin.*

1889. Tellurium and Lunarium, with clockwork. *Ernst Schotte, Berlin.*

1890. Tellurium and Lunarium.
F. Hornung, Langenbeutingen, Würtemberg.

1891. Apparatus intended to elucidate the **Apparent Motions of Planets** seen from the earth.
H. G. Van de Sande Bakhuysen, Director of the Observatory at Leyden.

The apparent motions of a superior planet are depicted on the inner surface of a cylinder. This apparatus was made by Professor Kaiser for his popular lessons on astronomy.

1892. Apparatus for demonstrating the **Path of the Moon** round the Sun, as an epicycloid, without cusp or loop.
Dr. K. Oppel.

When the handle is turned the moon will mark, by means of a pencil to be inserted in the socket under it, its serpentine path on a sheet of paper laid underneath.

1893. Model of the Paths of the Earth and of Venus, with movable balls on a stand, for demonstrating the position of the nodes and apses, inclination of the orbit, the period of Venus, culminations, &c. *J. J. Oppel.*

1894. Armillary Sphere of brass, to take to pieces, with horizon and azimuth, meridian, equator, ecliptic, declination, and polar circles, movable sun, &c. *J. J. Oppel.*

This sphere demonstrates many of the definitions of spherical astronomy: zenith and azimuth culmination, circumpolar stars, longitude and latitude, the seasons, hour-angles, sunrise and sunset according to time and place, length of the day, &c., &c.

1895. Apparatus for demonstrating (*a*) **Foucault's Pendulum Experiment,** and (*b*) the relation between the **Period of Revolution of the Pendulum** and **Geographical Latitude.** *J. J. Oppel.*

The apparatus, placed on a common centrifugal machine and turned slowly to the left, shows the maintenance of the plane of oscillation of the pendulum as respects its apparent revolution for the spectator, a revolution which the ball of the pendulum (painted half black half red) itself does not accomplish. *b.* With a movable tangent cone the instrument demonstrates, by means of some large diagrams, that, and why the apparent angular velocity is proportional to the sine of the geographical latitude.

1896. Apparatus for demonstrating the alteration of the date in journeys round the world, from west to east. Property of His Highness Prince Pless, Fürstenstein.
Committee of Breslau.

This instrument dates from the first quarter of the 18th century.

1897. Siderial Atwood's Machine, with a ball, which represents either the moon or a planet. *Chr. Trunk, Eisenach.*

The peculiarity of the apparatus and its object explained in the description which accompanies the model.

1898. Ring Sphere. *Dr. H. Löckermann, Hamburg.*

This armillary sphere, of which a more detailed explanation accompanies the instrument, is to be used for instruction in mathematical geography. It is to serve for object lessons, and makes therefore no pretence to scientific accuracy. The instrument demonstrates the apparent motion of the sun and moon, and of the more important constellations (49 constellations with 359 stars of from first to fifth magnitude) at any given place and at any given time.

1899. Projection Apparatus. *T. and A. Molteni, Paris.*

1900. Sigr. Descrivani's Orrery, by M. Pierret.
Conservatoire des Arts et Métiers, Paris.

1901. Wall Maps (11) for teaching Cosmography:—

1. The Ptolemaic system.
2. Tycho Brahé's system.
3. The Copernican system.
4. Comparative sizes of the sun and earth.
5. Comparative sizes of the planets (with map of Mars).
6. The seasons.
7. The phases of the moon.
8. Eclipses.
9. Parallax.
10. Comets.
11. Nebulæ. *Ernest Recordon, Geneva.*

1902. Three Astronomical Diagrams and Two Rules, with scales, for the solution of problems in spherical trigonometry.
Michael Elbe, Ellwangen.

The graphic representations drawn on the maps are called astronomical webs (diagrams), and the rules contain scales. By the assistance of a diagram and a scale any problem in spherical trigonometry can be solved without working out, a great advantage in navigation. It serves also on land for the determination of time and azimuth by means of one observation of a star.

In order to obtain the necessary accuracy in navigation, the drawing must be made as exact as possible by a machine, so that the accuracy of the solution, so far as that depends on the accuracy of the observing instrument, will be fully attained. Far greater precision will be arrived at by repetition, namely, by the easy reading of dozens of results which depend upon just so many observations. Even the most extensive table for nautical calculation cannot effect this; besides which the inverse problem, often so difficult of solution, becomes a pastime by means of this apparatus.

1903. Chart of the Stars, southern evening winter sky, in Central Europe.
Prof. J. J. Oppel, and Dr. K. Oppel, Frankfort-on-Maine.

1904. Specimens of Astronomical Diagrams, for teaching. White figures on black ground. *J. J. Oppel.*

In both instruments the circular plate (white on one side and black on the other) represents the plane of illumination, at *a* at the time of the equinoxes. The arrangement demonstrates as a necessary effect of a secular revolution to the right of the plane of inclination of the earth's axis; A the increase of the

ongitude of the stars; B the difference of the sidereal and tropical year; C the change of the pole star. The long wire at *a* can be fixed either in the direction of the pole (for A) or of the earth's axis (for C). The plane of the ecliptic is supposed horizontal; the appliance *a* must be turned to the right slowly on its pivot.

1906. (1.) **Diagram for Nautical Astronomy,** engraved on stone; with a printed explanation. (2.) Diagram of Nautical Astronomy. Handbook of Practical Nautical Astronomy.

1907. Orrery, by Cole: explanatory of eclipses. *Royal Society.*

1908. Celestial Globe. *Dietrich Reimer, Berlin (Reimer and Hoefer).*

1909. Celestial Globe of 80 cm. diameter, with complete equipment. *Dietrich Reimer, Berlin (Reimer and Hoefer).*

X.—ASTRONOMICAL DRAWINGS.

1910. Unfinished **Chalk Drawings** of **Lunar Craters,** made with the reflector of 3 feet aperture, at Parsonstown, by Mr. Samuel Hunter, assistant in 1860 to 1864. *Earl of Rosse, F.R.S.*

1910a. Chart of the Moon, drawn by hand by Tobias Meyer. *Prof. Dr. Winnecke, Strassburg.*

The highly interesting chart of the moon is the original drawing by Tobias Meyer, executed in the year 1750, which served for more than half a century as copy for all the maps of the moon used in nearly all the text-books. The autograph remarks on it, by the well-known Professor Ticktenberg, of Göttingen, show how and where the chart was preserved during the last century. It came into the possession of the exhibitor by a legacy of the late Privy Councillor Eisenlohr, of Carlsruhe.

1910b. Landscape of the Moon in relief, by Witte. *Prof. Dr. Winnecke, Strassburg,*

This view of the moon was executed by the celebrated Lady Frau Hofrath Witte, in Hanover, after her own observations. After her death it was presented to the exhibitor by her daughter Frau Stadtrath von Mädler.

1910c. A Series of Astronomical Engravings, from the Observatory of Harvard College. *J. Norman Lockyer, F.R.S.*

MODELS, &c. OF ASTRONOMICAL INSTRUMENTS.

1911. Model of one of the three **Smaller Domes** for the new Imperial Observatory at Vienna, now in course of construction at Mr. Howard Grubb's Works, Rathmines, Dublin. Scale, 1 inch to a foot. *Howard Grubb, F.R.A.S., Dublin.*

This dome is supplied with Mr. Grubb's improved shutter, by means of which, being perfectly balanced in all positions, the shutters of dome roofs are as easily managed as those of drum roofs.

This is accomplished by a set of counterpoises, equal in the aggregate to the whole weight of the shutter, which are lowered one after another into the place prepared for them. When the shutter is half open all the weights are deposited; the shutter being then balanced in itself. The chains then lap round a roller prepared for them, and as the shutter opens still further the weights are again raised up one by one as the shutter gets heavier and heavier towards the back.

If desired, this form of roof can also be made to open beyond the zenith by placing a pair of doors at base of shutter "chase," which open automatically, and allow the shutter to roll back.

1912a. 11 Photographs of the buildings of the Observatory and its principal instruments. *The Pulkowa Observatory.*

1912b. 10 Photographs of several auxiliary instruments lately constructed by M. Herbst, at the mechanical workshop of the Observatory. *The Pulkowa Observatory.*

1912c. Photographs of Mr. Newall's Observatory. *J. Norman Lockyer, F.R.S.*

1912d. Photograph of Galileo's Tribune at Florence. *J. Norman Lockyer, F.R.S.*

1912e. Photographs of the Old Astronomical Circles at Delhi. *Mrs. Norman Lockyer.*

1912f. Photographs of the Lamp in the Cathedral at Pisa (interesting in connexion with Galileo's observations). *Mrs. Norman Lockyer.*

1914. Three Photographs of Astronomical Universal Instruments. *F. W. Breithaupt and Son, Cassel.*

Astronomical universal instrument, portable. The movable circles have each two magnifying lenses for reading the seconds; the vertical circle is 33 cm., and the horizontal 50 cm. in diameter. The broken telescope has an aperture of 67 mm. and a focal distance of 80 cm., and is illuminated through the axis. The instrument revolves on the vertical axis; the horizontal axis is balanced on one plate only, and is invertable on spring rollers. One level rests on the horizontal axis, a second is attached to the carrier of the magnifying lens, and a third can be inverted on the same. The second vertical axis which serves as a counterpoise is graduated. The instrument itself was made in the year 1873 for the Japanese Government in Yokohama.

(2.) Astronomical universal instrument, portable.

This instrument is provided with two movable circles, of 25 cm. diameter, each having two magnifiers, with a side telescope of 27 mm. aperture and opposing vertical circle, the carrier of the magnifying lens being in the middle. By this arrangement the upper part of the instrument is kept low; it has also the advantage that, without alteration of position, the telescope, the two circles, as well as the numerating circle, can be observed. This instrument was constructed in 1875 for the Royal Mining Academy at Schemnitz.

(3.) Universal instrument, portable.

The circles are 20 cm. in diameter, the vernier reads to 10 seconds, the telescope of 40 m. aperture is at the side, the azimuth circle is movable and

the vertical circle attached to the telescope. All the verniers are covered with glass, and the alhidada of the vertical circle has a separate level. The instrument was made for the Imperial Observatory at Strasburg.

1914a. Photographs of Chinese Astronomical Instruments, enlarged by the Autotype Company from the original photographs by J. Thomson, F.R.G.S. *Autotype Company.*

No. 1. Ancient armillary sphere in the court of the observatory, Peking. This instrument was made under the direction of Ko-show-king (during the Yuen or Mongol dynasty, about the close of the 13th century), one of the most renowned astronomers in Chinese history, and at the time chief of the astronomical board. The instrument is solid bronze, of hugh dimensions and exquisite workmanship. A substantial metal horizon crossed at right angles by a double ring for an azimuth circle forms the outer framework. The upper surface of the horizon is divided into 12 equal parts marked with cyclical characters, the names of the 12 hours into which the Chinese divide the day and night. These are paired with eight characters of the denary cycle and four of the famous eight diagrams of the Book of Changes. The inside of the ring bears the names of the 12 states into which China was in ancient time divided. An equatorial circle is fixed inside the frame, within which a sphere turns on two pivots at the poles of the azimuth. This is made up of an equatorial circle and double ring ecliptic, an equinoctial circle, and double ring solstitial collar. The equator is divided into 28 unequal portions marked by the names of a like number of constellations of unknown antiquity. The ecliptic is divided into 24 equal parts. All these circles are divided into 365¼ degrees, corresponding to the days of the year, and each degree is divided into 100 parts, as the centenary division prevailed for everything less than degrees, till the arrival of Father Verbiest in the 17th century.

No. 2. Armillary sphere on the terrace of the observatory at Peking, made under the direction of Father Verbiest; *see* Thomson's "Illustrations of China "and its People."

No. 3. Celestial globe on the terrace of the observatory at Peking; *see* Thomson's "Illustrations of China and its People."

1914b. Model of Hipparchus' Astrolabe, showing how that astronomer observed longitudes, and was enabled to determine the processsion of the equinoxes. *J. Norman Lockyer, F.R.S.*

1914c. Two Photographs of the 25-inch Refractor constructed by Messrs. Cooke & Sons, of York, for Mr. Lewall, of Gateshead-on-Tyne. *J. Norman Lockyer, F.R.S.*

1914d. Collection of Photographs, illustrating various expeditions for observing Total Eclipses of the Sun. *J. Norman Lockyer, F.R.S.*

1914e. Three enlarged Photographs of the Moon, by Mr. Rutherford, of New York. *J. Norman Lockyer, F.R.S.*

1915. Atlas Cœlestis Novus. Stellæ per mediam Europam solis oculis conspicuæ secundum veras lucis magnitudines e coelo ipso descriptæ ab Eduardo Heis D. Math. et Astro. Prof. P. O. in

Academia regia Monasteriensi Coloniæ ad Rhenum 1872, impensis M. Du Mont Schauburg. Catalogus Stellarum.

I. Two volumes bound.

II. Thirteen plates for hanging on the wall.

Prof. E. Heis, Münster.

The Atlas Cœlestis Novus, the result of observation extending over 27 years, gives the appearance of the starry heaven as it is seen at the present day with the naked eye. It is more especially remarkable for containing, besides the stars of the 1st, 6th magnitude, those also of the 6th and 7th magnitude, which the author himself can easily distinguish. All the stars, without exception, are compared with one another in respect of magnitude by the naked eye, with the additional employment of other means of assistance; thus, among others, has been used the "method of sequences" of Sir John Herschel (*see* Results of Astronomical Observations at the Cape of Good Hope). The total number of stars observed by the author is 5,421, or 2,153 more than will be found in Argelander's Nova Uranometria. As no single star has been entered which has not been many times observed and compared, future observers will be able to judge whether in the course of centuries the sky has changed, whether any of the stars get brighter or darker, whether some have disappeared, or others come into view.

The author has paid particular attention to draw the milky-way with the greatest accuracy, and to make the brightness of the different stars in 5 degrees. For this purpose, the drawings made by Sir John Herschel of the milky-way in the southern sky were taken as models. The figures of the old constellations are copied from the classic figures on the celestial globe in the Farnese Museum at Naples. In the catalogue of the stars arranged according to the 57 constellations, their right ascensions and declinations, (Aug. 1855) are given; there are added also the numbers of Bayer and of Hamstur (according to Miss Caroline Herschel); and also the numbers in the catalogue of the British Association for the Advancement of Science, and other catalogues.

1916. Chronometrograph, for the determination of true time. (Original drawing.) *Prof. Dr. Prestel, Emden.*

1917. Pictorial Representation of the Solar System, for the demonstration of the relative sizes of the sun and planets, also of the relative distances of the planets from the sun, and of the inclination of their orbits to the ecliptic. (Original drawing.)

Prof. Dr. Prestel, Emden.

1917a. Photograph of the Sun, by Mr. Rutherfurd, taken with his triple combination. *J. Norman Lockyer, F.R.S.*

1917b. Enlarged Photographs of the Sun, taken by M. Janssen. *J. Norman Lockyer, F.R.S.*

1917c. Photograph of the Sun, taken by Professor Winlock, by a simple lens of 40 feet focal length.

J. Norman Lockyer, F.R.S.

1918. Chart of the whole Celestial Sphere in epicycloidal projection. *Dr. F. August, Berlin.*

This map gives a simultaneous view of the whole sidereal heaven. Each

constellation preserves its proper form, for the representation is conformable, that is, proportional in the smallest parts. There is no want of conformity at any point, not even at the poles, so that even there the meridians cut each other at the correct angle. By this means the spherical form is always pictured to the eye; the arrangement of the map is easily imagined, by supposing an elastic envelope to be stretched about a celestial sphere, then cut open and stretched on a frame. The course of the milky-way which follows one of the great circles of the heavens, and the parts comparatively free from stars which are at the poles of this great circle, are very well represented by means of this map. The map contains the stars from the first to the sixth magnitude.

The mathematical considerations which are necessary for accurately understanding the construction of the map will be found in the accompanying treatise: Ueber eine conforme *Abbildung der Erde nach der epicycloidischen Projection.* (Extract from the *Zeitschrift für Erdkunde*, Vol. IX., Berlin, 1874, published by Dietrich Reimer.

1919. Treatise on a **Conformable Representation** of the **Earth** by **Epicycloidal Projection.** (Extract from the Zeitschrift für Erdkunde, vol. IX., Berlin, 1874.)

Dr. F. August, Berlin.

XI.—MISCELLANEOUS.

1920. Vinot's Sideroscope. *T. and A. Molteni, Paris.*

1921. Apparatus, constructed by Professor Kaiser, for determining the absolute value of personal errors in observations on the transit of stars.

H. G. Van de Sande Bakhuysen, Director of the Observatory at Leyden.

The moment of the transit is registered by the action of a current. The construction of this instrument dates from 1858; the first observations were taken in 1859. (Dutch Records, Tome I., p. 193.)

1922. Observing Seat for Reflecting Telescopes, invented by the contributor. *E. B. Knobel, F.R.A.S., F.G.S.*

The observer sits as on horseback, and by simply raising himself off the seat, standing on the ground or on the movable footrests, as if in his stirrups, he can easily pull the seat up under him, and adjust it to the required height, without dismounting or moving from the eye-piece of the telescope. Releasing the ratchet wheel allows the seat to be lowered to any position.

1922a. Collection of Compounds of Silicon with various **Metals** for optical purposes.

1922b. Fittings for **Astronomical Telescopes.**

M. Lutz, Paris.

1923. Cooke's Lamp for illuminating the micrometric spider webs of astronomical telescopes. *A. A. Pearson, Leeds.*

The lamp is inserted in the brass body of the instrument, where it is held

by two projecting catches. The light, after passing through a condensing lens, is received by a rectangular prism placed at such an angle that the beam is totally reflected downwards into the window of the telescope, where its intensity and colour are modified by diaphragms. The lamp is suspended on a pivot, and also the framing and prism-box revolve from the bottom of the supporting pillar, so that it has a universal motion accommodating it to the position of the telescope. The weight of the end counterpoises the lamp, and the one at the side is the gravity poise. The top of the lamp is movable, and has attached a small tin chimney, which assists in promoting a draught and keeping it cool.

1924. Perpetual Almanac.
(Directions for use printed at the back.)
Gust. Schubring, Erfurt.

1924a. Calendar for Two Thousand Years.
M. Georges Sarasin, Geneva.

Lithographed sheet, framed and glazed, permitting the sight, by three openings, of portions of a second lithographed sheet which is capable of movement round a spindle issuing from the right side. These lithographed sheets are divided into sectors of a circle radiating from a common centre, which is at the same time the centre of motion of the second. They are covered with figures and explanations. An inscription denotes briefly the method of use.

USE.—If, by the motion given to the central disc by means of the spindle, the two figures which express the tens and units of a year, and the figure which constitutes—or the two figures which constitute—the hundreds (whether according to the Gregorian or Julian style), be brought into such a position that the latter be to the left and the former to the right, the calendar of that year will be given on the lower portion of the sheet. The days of the week will correspond to the days of the month in the radial direction, and to the months in the circular direction, whichever of the two styles may have been chosen. There is no occasion either to give a new movement to the disc, or to take into consideration the dominical letter, which is only a digression. Two of these *data* being given, the third may be found. When the three *data* are given, the years may be found, which, since the Christian era, have possessed them together.

The months of January and February are distinct according to whether it be a bissextile or ordinary year that is in question. In the former case, the tens and units figures, divisible by four, are separated by an empty space from the preceding in the table of years. A third designation of the two above-mentioned months is also perfectly suitable to the two classes of years, if the date of the year immediately preceding be formed by the movement of the disc.

It may also be ascertained to what day of the ordinary week corresponds any date during the thirteen years of the Republican style which followed the year 1792, by taking for the hundreds portion the zero of the Julian style.

1924c. Calendarium Perpetuum Mobile, eight Tables in glazed frame and in a stand. *Ch. A. Kesselmayer, Manchester.*

A perpetual calendar, which gives the solution of any chronological problem during a period of from 10,000 years before to 100,000 years after Christ. The tables, which are still in course of construction, will contain the principles of a "Standard Calendar," as invented by the author, the object of which is to demonstrate the errors and inaccuracies both of the Julian and Gregorian calendars.

Tab. I. Adjustable universal calendar key,
Tab. II. Adjustable annual calendar.
Tab. III. Adjustable astronomical calendar of the northern zone.
Tab. IV. Table for discovery of the theoretical epacts.
Tab. V. Table for finding the epacts to be applied.
Tab. VI. to VIII. contain : explanations and examples of the Calend. Perp. Mob.; adjustable universal calendar; adjustable indicator of dates; adjustable cylindrical indicator of week days; adjustable perpetual pocket calendar; annual pocket calendar for the year 1877 ; calend of the week days.

1924d. Reproduction of the Books on Astronomy, written by Dr. Alonso el Sabio, 13th century, from the original MS. at the Escorial. *Academia de Ciencias, Madrid.*

"Libros del Saber de astronsmia del Rey Don Alonso el Sabio" 5 vol., gr. in fol., Madrid.

These volumes contain an extensive account of astronomical science in the 13th century, the plates reproduce among other details the constellations there known, and the astronomical instruments used at the time.

1924e. A reproduction in plaster of a fragment of the Zodiac (Aries). The original, in stone, is at the Archæological Museum at Madrid. *Archæological Museum, Madrid.*

This was found, with other objects of a very remarkable kind, at Yecla, in the province of Alicante (Spain). It has an inscription in old Greek characters relating to the subject.

SECTION 12.—APPLIED MECHANICS.

South Gallery.—Ground Floor, Rooms B. C.

I.—PROPERTIES OF MATERIALS.

1925. Chinese Steel Helmets (2).

Bennet Woodcroft, F.R.S.

1926. Chinese Cane Helmets (2).

Bennet Woodcroft, F.R.S.

1927. Cast-iron Test Bars. Specimens to illustrate the forms and positions of fractures when exposed to a breaking load.

W. J. Millar, C.E.

The bars were of 36″ span, 2″ deep, and 1″ broad.

The load was applied at centre of bars. Straight fractures occurred when bars broke at, or close to, centre of span; curved fractures followed when bars broke at points more or less removed from centre.

1957b. Drawings of Hydraulic Apparatus for the study of the extension, compression, and flexion of prismatic bars. Constructed by Professor Wischnegradski.

Laboratory of Mechanics, Technological Institute, St. Petersburg.

This apparatus consists of a hydraulic cylinder, the piston of which bears a table supporting four iron columns, connected at the top by a strong cast-iron cross piece, that has at the centre a conical opening, and below a spherical excavation within which pivots a hemispherical cast-iron piece, traversed by a powerful iron screw fixed by two nuts; to this screw is attached the upper end of the bar subjected to the experiment of extension; the lower end of the bar is fastened to the large lever placed at the base of the apparatus and which pivots round an axle fixed in an immovable bearing. This lever is connected with the upper lever, by means of two iron braces suspended to one end of this lever; at the other end are hung a scale board for the weights used in calculating the tension effected. The ratio of the two arms of the lower lever is 5, and that of the two arms of the upper lever is 20. So that each lever being perfectly balanced the tension of the bar is exactly 100 times that of the weight on the scale board. By means of the screw described above, and by inverting the intermediate iron pieces, it is possible, with this apparatus, to experimentalise upon bars of any length provided they do not exceed 10 feet English.

Drawing No. 1 represents the apparatus arranged for experiments of extension.

Drawing No. 2 represents the apparatus arranged for experiments of flexion.

Drawing No. 3 represents the apparatus arranged for experiments of the compression of long bars.

The deformations in the bars occasioned by this apparatus are measured with a cathetometer constructed by Mr. Brauer, and the primitive section of the bar with an apparatus by the same engineer. The correctness of all these registerings is given in $\frac{1}{200}$ of the millimeter.

II.—SPECIAL COLLECTIONS.

Collection of the original Models of Steam Engines and other Machines of James Watt. Presented to the South Kensington Museum by Gilbert Hamilton, Esq.

1928a. Imperfect Model of method of converting reciprocating into rotative motion by means of teeth or pins fixed to the connecting rod, which take hold of teeth in a wheel, and cause it to revolve. Some point of the connecting rod being guided by a pin, moving in a groove, so as to keep the teeth or pins always engaged in the teeth of the wheel.

This method of converting reciprocating into rotative motion is included in Specification of Patent granted to James Watt, dated October 25th, 1781.

1928b. Two Fragments of a Model, consisting of wood rods with oval holes geared internally, and apparently belonging to one of the models selected from the Soho Works by the late Sir Francis Smith, as an illustration of one of the methods of converting reciprocating circular motion.

1928c. Model of Grinding Mill, 6 pairs of stones in two sets of 3 pairs each, each set driven by a spur wheel with bevil gearing. The two fly wheels are connected and driven by pin and connecting rod.

1928d. Model of Grinding Mill, with six pairs of stones, in two sets of three pairs each. Each set driven from one spur wheel by bevelled gearing.

The two fly wheels are connected, and driven by one connecting rod, fitted with two sets of stepped sun and planet wheels.

1928e. Model of Rolling and Slitting Mill, driven by two connecting rods, on one beam, and fitted with sun and planet stepped gearing.

This improvement, consisting of new methods of applying the power of steam engines to move mills for rolling and slitting iron and other metals, is included in Specification of Patent, granted to James Watt of Birmingham, and dated April 28th, 1784.

1928f. Model of Rolling Mill, driven by a connecting rod, fitted with stepped sun and planet motion, and with two fly wheels.

1928g. Model of two Tilt Hammers, at right angles to each other, one hammer actuated at the tail by cams, the other by lifting cams, driven by one connecting rod fitted with stepped sun and planet motion.

NOTE.—Part of the above model is missing, and the helve of one tilt hammer is broken.

1928h. Model of Wheel (probably for grinding). With sliding axle.

1928i. Fragment of Model (probably a pump bucket).

1928k. Models on a Stand, of four trussed beams, probably used experimentally for testing the strength of different methods of trussing.

1928l. Fragment of a Model of a Frame for a Machine.

1928m. Fragment of a Frame.

1928n. Model of a Horse Mill, with roller and trough, apparently designed for crushing material.

1928o. Model of a Train of Wheels.

1928p. Model of Beam and two connecting Rods with universal motion at their upper ends, and connected to transverse hinged links at their lower ends.

1928q. Model of Beam Pumping Engine, single acting and condensing, worked by tappet valve motion.

1928r. Model of double acting Beam Condensing Engine, conical valves worked by eccentric.

1928r. Model of inverted Cylinder, direct acting pumping engine with tappet valve motion.

1928s. Sectional Model of Beam Engine, worked by eccentric and hollow valve.

1928t. Sectional Model of Engine, with shifting eccentric for altering valve.

1928u. Model of a Pair of Tilt Hammers, alongside each other. Two beams and connecting rods, with cranked pins at an angle to each other, and one of the wheels provided with a balance weight.

(NOTE.—Part of the above model missing.)

1928v. Fragment of a Model with part of Sun and planet motion.

1928w. Fragment of a Model with Sun and planet motion and weighted disc.

1928x. Fragment, an arch head.

1928y. Model of a Water Wheel.

1928z. A Measuring Apparatus, with Micrometer Screw, for taking end measures.

1928aa. Model of Garnet's Patent Friction Rollers.

1928bb. Model used for Testing Pressure due to Vacuum.

1928cc. Model of Valve with Universal Joint.

1928dd. Brass Model in two Pieces.

1928ee. Model used in experiments on Governor.

1928ff. Experimental Model.

1928gg. Experimental Model.

1928hh. Experimental Model.

1928ii. Original Model of Cylinder with separate Condenser.

1828jj. Model of Surface Condenser.

III.—PRIME MOVERS.

1930. Original **Model** of **Stirling's Air-engine.** Made by the inventor. *University of Edinburgh.*

1931. Rotary Steam Engine. Designed and made by the Rev. Patrick Bell.

Lent from the Patent Office Museum by the Commissioners of Patents.

1932. Sectional Model of a **Cabinet Steam Engine.**

Lent from the Patent Office Museum by the Commissioners of Patents.

This is a sectional model of a steam engine in the Patent Office Museum, and was made for the purpose of showing the following improvements in the steam engine made by James Watt. (The engine in the Patent Office Museum was the property of James Watt.) Improvements above referred to :—

a. Making the engine double acting.

b. Keeping the cylinder heated while the engine is at work by surrounding it with steam.

c. Using a separate condenser and air pump.

d. Parallel motion.

e. The governor.

f. The D slide valve.

1933. Drawing of "Head's Patent Prime-mover."

Jeremiah Head, M.I.C.E.

Being an inverted, direct-acting, non-condensing steam-engine, with steam-jacketed cylinder and covers, cylindrical slide valves, and variable expansion gear, controlled by a liquid-cataract parabolic governor, and balanced throughout for running at a high speed.

1934. The **Locomotive Engine "Rocket,"** constructed, by Messrs. Stephenson & Co. in 1829, to compete with other engines on the Liverpool and Manchester Railway, where it gained the prize of 500*l*. The Liverpool and Manchester Railway was formally opened for passenger traffic on the 15th September 1830.

Lent from the Patent Office Museum by the Commissioners of Patents.

1934a. The Puffing Billy, the oldest locomotive engine in existence, and the first which ran with a smooth wheel on a smooth rail, was constructed in 1813 by *Jonathan Foster*, under *William Hedley's* patent, for Christopher Blackett, Esq., the proprietor of the Wylam Collieries near Newcastle-upon-Tyne. This engine, after many trials and alterations, commenced regular working in 1813, and with tender and two trucks, a total load

amounting to fifty tons ran, at an average rate of six miles an hour. It (he ?) was kept at work until the 6th June 1862, and was then purchased for the Patent Museum.

H.M. Commissioners of Patents.

1935. Wood Model of **Disc Engine.** (Taylor and Davies' Patent, 1836.) *Bennet Woodcroft, F.R.S.*

1936. Original Model of **Trevithick's Locomotive Engine.** (Trevithick's Patent, 1802.)

Bennet Woodcroft, F.R.S.

1937. Model of a **Caloric Engine** (unfinished).

Bennet Woodcroft, F.R.S.

1938. Model of Reversing Apparatus for **Locomotive Engines.** *Bennet Woodcroft, F.R.S.*

1939. Models (2) of **Rotary Engines.**

Bennet Woodcroft, F.R.S.

1939a. Model of Locomotive, of great adherent power, working by means of six clogs.

M. Adolphe Fortin Hermann, Paris.

(This model belongs to the Conservatoire des Arts et Métiers.)

1940. Working Model of **Stirling's Air Engine,** presented by the inventor, the Rev. Robert Stirling of Galston, to the Natural Philosophy Class of Glasgow University, and used constantly for lecture illustrations. *Sir William Thomson.*

1941. Model of **Dawes' Compound Stationary Engine.** In this the low-pressure cylinder is horizontal, and the high pressure is arranged over it, at an angle of 30° to the centre line of low pressure. The connecting rods couple to a single crank; the air pumps and condensers are driven off the low pressure crosshead, and being two in number are arranged on each side of connecting rods. *Henry S. Holt, C.E., Leeds.*

1942. Model of Agricultural Locomotive Engine, fitted with patent side-plate brackets. *Aveling and Porter.*

This represents one of Aveling and Porter's road locomotive engines. The *single* cylinder is placed on the forward part of the boiler, and is surrounded by a jacket in direct communication with it; the steam is taken into the cylinder from a dome connected with the jacket. Priming is by this means prevented, the use of steam-pipes either inside or outside the boiler is rendered needless, and a considerable economy in fuel is effected. The crank-shaft brackets are formed out of the side plates of the fire-box extended upwards and backwards in one piece, so as not only to carry the crank-shaft, but to provide bearings also for the counter-shaft and driving-axle, in the most convenient position. This arrangement produces a combination of much strength and lightness, reduces to a minimum the loss and annoyance from leakage at strained bolt holes, and unites all parts, peculiarly exposed to

injury by jarring, with such firmness as to give almost absolute security against such injury on even very rough roads. The driving wheels are of wrought iron, and are fitted with compensating motion for turning sharp curves without disconnecting either wheel; they carry about 85 per cent. of the weight of the engine. The engine is steered from the foot-plate. The boiler is made of best quality plates, and tested with cold water to 200 lbs. on the square inch; the fire-box is of Lowmoor iron.

1943. Original Model of Newcomen's Steam Engine.
Council of King's College, London.

1943a. The Pulsometer (Hall's patent).
Hodgkin, Neuhaus, and Co., London.

Self acting steam pump, a novel application of the general principle involved in Savery's engine, A.D. 1702. The result is produced by the pressure of the steam from the boiler upon the surface of the water in each chamber of the pump alternately, without the intervention of any steam piston or plunger, and the water is lifted into the chambers by a vacuum produced without injection or surface condensation. The action of the steam ball which governs the pulsations is purely automatic, and the moving parts, including four valves, are only five in number.

1944. Model of Captain Savery's Steam Engine. This form is a modification by Dr. Desaguliers, constructed about 1717. The first complete engine of this kind was made for the Czar of Russia (Peter the Great), for his garden at Petersburg. 1717 or 1718. *Council of King's College, London.*

2137. Model of a **Direct-acting Cornish Pumping Engine,** with cataract.
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

This (also with open cylinder) has a cataract of simple construction, and a systematically arranged valve motion.

The model serves, in the first place, to illustrate the general nature of click-trains used as valve gear, and their application by means of a plug rod and tappets worked from a beam. It also shows in particular the mode of employing a condenser in a single-acting engine, where three valves (admission, exhaust, and equilibrium) are necessary, with their three separate weigh shafts and wipers, clicks, weights, and levers. The commencement of the expansion is shown very distinctly by the closing of the admission valve. The pause at the end of the "indoor" stroke is effected by means of the cataract, which is filled with petroleum; the action of this mechanism can be very distinctly observed. With a slow motion of the cataract, it can also be easily noticed that the exhaust valve opens a little sooner than the steam valve, in order that a sufficient vacuum may exist upon one side of the piston before the steam is admitted upon the other.

The condenser itself is omitted in order to simplify the model and to make the complicated valve gear somewhat more easy to understand. A lever for the injection valve only is shown, to show that this valve must be opened before the engine can start.

For simplification, the cataract which determines the short pause at the end of the "outdoor" stroke is also omitted.

2136. Stationary Direct-acting Steam Engine (model).
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

The cylinder and valve chest are opened so as to show the various parts. The eccentric is displaceable with reference to throw and lead; accordingly the valve rod and valve are changeable.

This model shows the general arrangement and essential details of a stationary direct-acting engine, and is arranged specially to demonstrate the relative motions and positions of the piston and the slide valve, and the mechanisms connected with them.

It shows :—

1. The dead points of the machine;
2. The necessary relative positions of eccentric and crank;
3. The way in which a steam engine is compelled to move in one direction.
4. The lead of the valve and the eccentric, and their influence upon the steam admission;
5. The lap of the valve and its connexion with the angular advance of the eccentric and the expansion of the steam ;
6. The irregularities in steam distribution and in the transmission of motion to the fly-wheel, caused by the obliquity of the connecting-rod; and
7. The effects upon the steam distribution of an eccentric rod of wrong length or an eccentric put in a wrong position.

1944a. Working Model of latest improved horizontal high-pressure coupled winding engines for coal, copper, iron, salt, and other mines. *Messrs. Robert Daglish and Co., Lancashire.*

2141. Model of a Horizontal Steam Engine, with reversing gear (Gooch's link).
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

This model is intended to illustrate the action of the link motion generally, and especially that with adjustable block.

The link can be worked in two ways. Either its centre can be suspended and an eccentric rod connected with each of its ends, or its centre can be fixed, and one eccentric rod only used; an arrangement often employed, for example, in hoisting engines.

It shows very distinctly that with two eccentric rods with their eccentrics placed 180° apart, the centre of the link moves to and fro, and that this error can be almost entirely prevented by giving the eccentric a little advance.

2143. Horizontal Steam Engine, with reversing gear (Stephenson's link).
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

Along with the above model this shows the two chief systems of link reversing gear, their differences, and their comparative advantages and defects. The link has here a different form to that employed in the last case, partly simply for the sake of variety, and partly to show the influence of the position of the point of suspension upon the motions of the link.

Models of mechanisms :—

The eccentric is here also adjustable for variations of lead.

1945. Atmospheric Gas Engine. Otto Langen and Crossley's joint patents. Actuated by the vacuum resulting from the explosion of common coal gas and air. *Crossley Brothers.*

In this engine, which works by the vacuum resulting from the explosion of common coal gas and air, the piston is not, as is usual, connected with the shaft on both up and down stroke, but on down stroke only. It is thus at liberty to fly up freely from the force of the explosion, which takes place at the bottom only, and by driving the piston before it empties the cylinder of air through its open upper end. The return of the air on the down stroke yields the driving power, and turns the shaft by means of a friction clutch, to which the piston is geared by the rack. The vacuum beneath the piston in equal to about 11 lbs. per square inch for the greater part of the down stroke. The governor does not act, as is usual, by increasing or decreasing the power of each stroke, but by varying the number of strokes, each being of the same power. This is done without materially changing the speed of the shaft. Three or four explosions per minute are generally sufficient to turn the engine itself, and as a maximum of 30 to 35 may be made, there is a balance of, say, from 26 to 32 strokes or explosions per minute left to be applied to useful work under the regulation of the governor. As this engine can be started and stopped at a moment's notice, giving full power at once, and is free from the risks of a boiler explosion, it is peculiarly suited for use as a motor in a laboratory. The consumption of gas is seldom over 2*s.* 6*d.* worth per week for a 1-HP. engine. The engine as here exhibited contains many quite recent and very important improvements.

1946. Sectional Model of a **Steam Engine,** with expansion. *Paul Lochmann, Zeitz.*

1947. Sectional Model of a **Locomotive.** *Paul Lochmann, Zeitz.*

1948. Wall-diagrams illustrating the **Hot-air Engine.** *Prof. von Gizycki, Aix la Chapelle.*

1949. Wall-diagrams illustrating the **Gas Engine.** *Prof. von Gizycki, Aix la Chapelle.*

1950. Wall-diagram illustrating the **Steam Engine,** with continuous expansion. *Prof. von Gizycki, Aix la Chapelle.*

These diagrams are used in Prof. von Gizycki's lectures on description and theory of machines.

1951. Turbine to act as prime mover for physical laboratories. Head of water necessary, 10–20 met.; measure of water, 1 lit. per sec.; effective power about 10 meterkilo. *Prof. Wüllner, Aix la Chapelle.*

This turbine, with constant water pressure, is exceedingly steady in its action, and thus is specially suited for apparatus that require a constant velocity of rotation. With the fall of 18 mètres available in air, and a water supply of about one litre per second, the effect of the machine is equivalent to one man's power.

1952. Working Model, on a 1½ inch to 1 foot scale, of a four wheel locomotive engine. Built at Alexandria in 1862 for service of Egyptian Railway between Alexandria and Suez. Jeffrey Bey, C.E., Great George Street, Westminster. *South Kensington Museum.*

Note.—The model represents an engine of the outside-cylinder "Stephenson" type, on four wheels, and is a tank engine of a peculiar form.

The water tank is hung beneath the boiler; the coal boxes are placed over the fire-box of the boiler.

To the model are attached the necessary accessories of a locomotive engine, viz., lifting screw jack with traverser, screw keys, fire bars, lights, stoking irons, &c., complete.

1953. Model, in wood and brass. Sectional working model of the cylinder, piston, slide-valve, eccentrics, link motion, and other parts of a locomotive engine. Jeffrey Bey, C.E., Great George Street, Westminster *South Kensington Museum.*

Note.—This model also indicates the variable expansion and cut-off of steam in the engine cylinder.

1954. Drawing, on a scale of ½-inch to 1 foot, of a patent horizontal high-pressure condensing steam engine; designed and made by the Reading Iron Works Co. Reading Iron Works Co., Limited, Reading. *South Kensington Museum.*

Note.—This drawing shows a side elevation of the engine and a through plan.

It represents an engine of 25 horse-power nominal; having variable expansion gear, fly wheel, governor, feed pump, and condenser.

A similar engine was employed to drive a part of the British machinery in motion at the Vienna Universal Exhibition for 1873.

1955. Photographs, two, of a compound horizontal-cylinder condensing steam engine. Constructed by the donors in 1873. 120 indicated horse-power. W. and J. Galloway and Sons, Engineers, Knott Mill Iron Works, Manchester.

South Kensington Museum.

Note.—One photographic view is of the cylinder end of the engine; the other shows the fly-wheel, crank shaft, and governor motion, &c.

The high-pressure cylinder is 14 inches in diameter. The low pressure cylinder is 24 inches in diameter. The stroke of the piston is 2 feet 6 inches.

This engine was employed in driving a portion of the British machinery in motion at the Vienna Universal Exhibition of 1873.

1956. Photograph of Brotherhood's patent three-cylinder high-pressure steam engine, arranged as a stationary engine. The engine was designed and patented by Mr. P. Brotherhood in 1872–73. Brotherhood and Hardingham, Engineers, London.

South Kensington Museum.

1956a. Model of **Brotherhood's** patent **Three-cylinder Hydraulic engine** arranged for turning a capstan, the pressure being supplied to the engine by a Brotherhood's patent three-cylinder pump. *Hydraulic Engineering Company, Limited, Chester.*

1957. Working Model of a stationary steam engine.

Royal Trade School, Halle (Director, Dr. Kohlmann).

1957a. Model of Goods Locomotive.

Museum of the Technological Institute, St. Petersburg.

1959. Two Hydrostatic Rotary Engines with table to which eccentric motion is conveyed. The machines were invented by the exhibitor for the purpose of facilitating the solution, aggregation, or precipitation of chemical compounds, which they do as effectually in half an hour as if the solutions were allowed to stand for 24 hours (tested by quantitative experiments). The table is open in the centre, so that a beaker or flask may be heated by a Bunsen burner, and it is furnished with double-sliding clamps so as to securely hold the vessel in its place.

A, engine intended for delicate quantitative experiments.

B, engine for ordinary purposes.

Joseph William Thomas, Cardiff.

1960. Working Model of Atmospheric Engine, with sun and planet motion. *Glasgow Mechanics' Institution.*

1963. Model of a patent direct acting "Universal" steam pump, as used for pumping water from mines, or for other purposes where simplicity of construction and economy of space are matters of importance. *Hayward Tyler & Co.*

1964. Drawing showing a longitudinal and a cross section through the steam cylinder of "Universal" steam pump, showing steam piston with slide valve therein, and the arrangement of ports. *Hayward Tyler & Co.*

1965. Wood Model to show the action of a recent improvement in the mechanism of the "Universal" steam pump for high "lifts;" the slide valve being contained in a valve chest outside the cylinder, and allowing of the use of an ordinary steam piston, thus allowing a longer stroke without lengthening the cylinder. *Hayward Tyler & Co.*

1966. Drawing illustrative of the arrangement of slide valve, &c. for the "long stroke" "Universal" steam pump for high lifts. *Hayward Tyler & Co.*

1967. Model of horizontal engine (novel girder pattern), with portion of cylinder removable to show the action of a variable automatic expansion valve gear (Rider's patent), controlled directly by the governor. The expansion valve works on the back of the lower valve by a separate eccentric in the ordinary manner, but owing to its triangular shape, and the form of the parts, the point of cut-off changes according to the angular motion of the valve round its spindle. This angular rotation is produced by the rise and fall of the governors through rack and quadrant. Any acceleration in speed thus affects the rise and fall of the governor balls, and accelerates or delays the time of steam admission.

Hayward Tyler & Co.

1967a. Pumping Machinery (being largely used for raising fluids, and the engine used as a prime mover.)

Hayward Tyler and Co.

In the pumping machinery, Nos. 1967*a* and 1963, great simplicity of construction and durability of parts. In Nos. 1964 and 1965, combined with the above is also the obtaining a longer stroke, means of starting from the outside by a lever, and the obtaining of a "rest" at each end of the stroke to allow time for the pump valves to close easily.

1968. Bailey's Patent Quadruple Engine House Recorder registers on a diagram, which is removed, examined, and replaced every 24 hours, the varying pressure of the boiler and speed of the engine during that time. It consists of a steam pressure gauge, and a rotary speed indicator which registers on the diagram round the revolving drum, an eight-day timepiece which actuates the drum and indicates the time, and a thermometer, all complete in French polished mahogany case, with closet for the safe keeping of tools, scientific instruments, &c.

W. H. Bailey & Co., Manchester.

1968a. Model of a Steam Engine with **Glass Cylinders,** for demonstration, 1852. *M. Eugène Bourdon, Paris.*

1978. Holt's Automatic Cylinder Drain Valves.

The object of this is to let out condensed or priming water from steam-engine cylinders. The valves open automatically at each exhaust, or when the engine stands, and remain open until the admission of steam, when they close, and prevent waste of steam.

Henry S. Holt, C.E., Leeds.

1979. Model of Dawes' Balanced Slide Valve.

The peculiar advantage of this consists in the mode of making an elastic joint between the relief frame and back of valve by means of a steel plate, secured to both in such a manner as to form practically one piece, thus avoiding leakage and the necessity of frequent attention. *Henry S. Holt, C.E., Leeds.*

1981. Model of Robey and Co's. semi-portable mining and winding engine. Richardson's patent. Robey and Co., Lincoln.

South Kensington Museum.

1982. McCarter's Patent Condenser, applicable to steam engines, and other purposes where a vacuum is required by the condensation of steam, without an air-pump being applied, and drawing its own injection water. *J. Wood.*

The condenser consists of two chambers, one above the other. The upper chamber (H) is for condensing the steam, the lower one (G), with the two tappet valves (C and D) opening into it, removes the condensed water from the upper chamber into the hot water cistern, whence it flows away.

The exhaust steam from engine enters at A, meets the injection water

entering at B, and is condensed, thus forming a vacuum, the water falling to the bottom of chamber (H). To remove this water, a vacuum is alternately created and destroyed, six times per minute only, in the lower chamber (G), by alternately raising the steam or water tappet valve (the steam supplying the tappet valve being reduced by reducing valve to $2\frac{1}{2}$ lbs. pressure). On vacuum being created in lower chamber, the water collected in upper chamber is drawn down through india-rubber foot valve (E); and on vacuum being destroyed in lower chamber, the water falls out through the delivering valve (F) into waste water cistern.

1983. Fourneyron Turbine, $\frac{1}{5}$th scale, by M. Clair.
Conservatoire des Arts et Métiers, Paris.

1990. Working Model of Whitelaw and Stirrat's Patent Water-Mill Turbine. *Glasgow Mechanics' Institution.*

The water-mill acts on a principle similar to that of the well-known "Barker's mill," but the arms are bent, and otherwise shaped, so as to allow the water to run from the central opening out to the jet-pipes.

1991. Working Models of three sets of Waterwheels, viz., undershot wheel, overshot wheel, and breast wheel.
Glasgow Mechanics' Institution.

1992. Model of Watt's Steam Engine.

1993. Model of the High-pressure Engine.
Prof. Meidinger, Carlsruhe.

The models are made of sheet-metal on pasteboard, are very durable, and show very clearly the relations of valve motion to piston motion.

IV.—RESERVOIRS OF ENERGY.

1994. The **First Hydraulic Press** ever made. Patented by Joseph Bramah, A.D. 1795, No. 2,045.
Lent from the Patent Office Museum by the Commissioners of Patents.

1995. Weisbach's Apparatus, for illustrating experimentally the laws of **Hydraulics,** and for the determination of hydraulic co-efficients. Large reservoir for the attachment of mouth-pieces and orifices under different heads. Gauging vessel. Smaller reservoir for the attachment of notches and open channels. Length of open channel. Collection of orifices, notches, mouth-pieces, &c. *Lieut.-Col. Chesney.*

Boilers, Injectors, Pressure Gauges, etc.

1969. Drawing, water-colour, on a $\frac{1}{2}$-inch to 1 foot scale. A pair of double flue tubular Cornish boilers for high-pressure. Adamson's patent. D. Adamson & Co., Engineers, Hyde Junction, Manchester. *South Kensington Museum.*

Note.—Two of these boilers were lent to H.M.'s Commissioners for the Vienna Universal Exhibition of 1873, for use in supplying steam to drive the British machinery exhibited in motion.

The drawing shows front or firing and elevation of boilers; longitudinal elevation with brick setting.

Longitudinal sectional elevation, showing arrangement of flues; blow-off, feed, and other pipes. Brick settings.

Two cross sections.—One through centre of boilers; the other through back end, showing brick setting, flues, &c.

1970. Sectional Model, in brass, showing the tubular arrangement, water spaces, and circulation of Richardson's patent vertical high-pressure steam boiler. Robey & Co., Limited, Engineers, Lincoln. *South Kensington Museum.*

1971. Drawing of Richardson's patent vertical high-pressure tubular steam boiler. Robey & Co., makers. Robey & Co., Limited, Engineers, Lincoln. *South Kensington Museum.*

Note.—The drawing shows a sectional elevation indicating the water circulation and the direction of the fire and products of combustion. Also a sectional plan of the boiler.

1972. Drawing, on a $\frac{3}{4}$-inch to 1-foot scale, of Howard's patent tubular safety land boiler; for high-pressure. J. and F. Howard, Engineers, Bedford. *South Kensington Museum.*

Note.—The drawing illustrates a front view of the boiler; longitudinal through section and plan. A cross section.

On a scale of $\frac{1}{4}$ full size is shown the detail of the water tube connexions.

These boilers are made by the Barrow-in-Furness Ship-building Company.

1973. Drawing, on a $1\frac{1}{2}$-inch to 1-foot scale, of Messrs. A. Chaplin & Co.'s patent vertical tubular high-pressure steam boiler. Alexander Chaplin & Co., Engineers, Glasgow. *South Kensington Museum.*

Note.—The drawing shows vertical through sections. Two plans of the disposition of the upper and lower tubes.

1974. Drawing, sectional, on a 3-inch to 1-foot scale, of an improved vertical high-pressure steam boiler, having horizontal water tubes with "Nozzle" ends, to assist the water circulation. From the construction of the tubes with Nozzle ends this boiler is called the "Nozzle" boiler. Reading Iron Works Company, Limited, Reading. *South Kensington Museum.*

Note.—The drawing shows a through sectional elevation of the boiler, and a sectional plan of the arrangement of the tubes; the circulation of the water, together with the direction of the fire and products of combustion. Scale 3 inches to 1 foot.

1975. Steam Pump. Horizontal direct-acting steam engine and pump for feeding steam boilers with water, or for pumping

and draining purposes. Cope and Maxwell's Patent. Hayward Tyler and Co., 84, Whitecross Street, E.C.

The steam cylinder is 5 inches in diameter. The stroke is 7 inches.

The pump plunger is 3 inches in diameter.

The valves are balls of india-rubber.

The pump will raise 2,000 gallons per hour, forcing 120 feet vertically. *South Kensington Museum.*

1976. Three **Models,** in brass, showing in section the arrangement of Giffard's patent injector for feeding steam boilers with water. Sharp, Stewart, and Co., Engineers, Manchester, and Victoria Street, S.W.

a. Giffard's own patent injector in section.

b. Giffard's injector in section, with the patent adjustment of Messrs. Robinson and Gresham.

c. Giffard's injector in section, with Seller's patent adjustment. *South Kensington Museum.*

1977. Accessories.—Pressure Gauges, for **Engines, Boilers, &c.** Schäffer and Budenberg, 23, Lower King Street, Manchester.

a. A 5-inch Pearson's patent lubricator for steam cylinders, and other working parts of machinery.

b. Mercury vacuum gauge for condensing steam engines.

c. Thermometer for measuring high temperatures.

d. Bourdon's patent steam-pressure gauges, for high and low pressure boilers.

e. Bourdon's patent vacuum gauges.

f. Schäffer's patent steam-pressure gauges for high and low pressure boilers. Two of these gauges are in section showing interior arrangement.

g. Schäffer's patent vacuum gauges, for condensing steam engines, &c.

h. Schäffer's patent hydraulic-pressure gauges, with maximum indicators.

i. Blast furnace gauge, mercury; indicating 6 lbs. pressure.

k. 7-figure counter, in section, for counting steam engine revolutions and speeds of machinery. *South Kensington Museum.*

1996. Working Model of a Hydraulic Ram, arranged with glass air vessels, so as to show the action of a column of air and pulsations of delivery valve. *K. W. Hedges & Co.*

This ram will raise one gallon of water per minute 8 ft. high by use of four gallons of water falling 2 ft.

V.—REGULATORS.

1997. Spherical Governor for Steam Engines. Patented by John Bourne.

Lent from the Patent Office Museum by the Commissioners of Patents.

1998. Governor for Steam Engine. *Gros, Paris.*

1998a. Gyrometric Governor for Steam Engines. *Messrs. Siemens Brothers.*

It consists of an open cup of parabolic shape, fixed upon a vertical spindle, and caused to revolve within the closed chamber containing the liquid, the bottom of the cup being open and always immersed below the surface of the liquid. When the cup is made to revolve rapidly, the liquid contained in it rises round the sides of the cup and sinks in the centre, the surface of the liquid assuming the inverted parabolic form; and on reaching the edge of the cup it overflows into the surrounding chamber, while at the same time a fresh supply of liquid is drawn into the cup through the opening in the bottom; and the power absorbed in putting the overflowing liquid into motion offers a continuous resistance to the rotation of the cup. On a level with the edge of the cup, a series of fixed vanes are placed round the circumference of the external chamber, and a corresponding set of blades are also fixed round the outside of the cup just below the rim, so that the sheet of liquid overflowing from the edge of the revolving cup is thrown against the vanes, and by these is thrown back against the blades on the cup, whereby the overflowing liquid is made to offer an additional resistance to the rotation of the cup.

The internal radial arms uniting the shell of the cup to the centre boss serve to communicate the rotary motion to the liquid inside the cup, while the bottom of the external chamber is provided with a number of radial ribs, for the purpose of checking rotary motion in the liquid outside the cup.

So long as the cup is driven at a constant speed, the overflow is constant, and produces an absolutely constant resistance; and, hence, if the cup be driven by a constant driving power, independent of the engine, its speed is as uniform as that of a chronometer, within a very small margin of variation, which is definitely fixed; and it continues revolving at an unchanging speed, totally independent of the engine, and consequently affords the means of forming a governor for controlling the speed of the engine to a constantly uniform rate.

1999. Model of Holt's Injection Water Regulator.

This is an automatic valve for regulating the supply of injection water admitted into steam-engine condensers, according to the requirements of the vacuum. It is useful in engines having a very variable load, and where water is taken from town's water-works for condensation. *Henry S. Holt, C.E., Leeds.*

1999a. Series of **Models** of **Governors,** &c. for **Steam Engines,** invented by Thomas Silver, of Philadelphia.

a. Differential marine governor.
b. Method of adjusting pneumatic governors when in motion.
c. Marine governor.

d. Combined isochronal and centrifugal governor.
e. Model showing T. Silver's earliest attempts at combining centrifugal and isochronal principle in his marine governor.
f. Reversible link motion.
g. Method of equalising the tension of a spring when in action.
h. Marine governor.
i. Marine governor.

2000. Model showing the effect of hanging the **Arms** of a **Governor** from different points with respect to the axis of rotation. *Jeremiah Head, M.Inst.C.E.*

By turning the horizontal sheave upon the model with gradually increasing velocity, it will be seen that the cross-armed, or approximately parabolic governor, goes through its range with the least variation of speed. Next in efficiency is that wherein the arms are hung from the central axis, whilst the very common form wherein the arms are hung externally is the least efficient, or, in other words, permits the greatest variation in speed between fully opening and fully closing the throttle-valve.

2001. Drawing, half the actual size, of a **Regulator** for a **25 Horse-power Boiler.** *M. Cleuet, Paris.*

This appliance is fixed to the inside of the furnace with an inclination of a few centimetres, in such a manner that the plane of the water level proper to be maintained passes through the upper tube at a point about half its length.

Connected with the boiler, on one hand, and with the feed pipe on the other, this appliance constitutes a kind of weight thermometer, the expansion and contraction of which depend upon the position of the water level in the boiler, and determine the flow by a discharge of the excess of water injected by the feed pump, which works uninterruptedly.

495. Rack and Snail of Clock, to regulate the number of blows struck each hour. *Council of King's College, London.*

496. Model of Chronometer Escapement. *Council of King's College, London.*

497. Model of Lever Escapement. *Council of King's College, London.*

498. Model of Horizontal Escapement. *Council of King's College, London.*

499. Model of Locking Plate of Clock, to regulate the number of blows struck each hour. *Council of King's College, London.*

2010. Gyrograph. *Prof. von Gizycki, Aix-la-Chapelle.*

This instrument serves in investigating the degree of inequality in the velocity of rotation of machine-shafts. The paper drum has rotation and axial velocity. The vertical deflections of the pencil from its lowest position are proportional to the increase of angular velocity of the shaft under examination. The instrument is driven by the latter by means of disc and cord.

VI.--THE APPLICATION OF THE PRINCIPLES OF MECHANICS TO MACHINERY AS EMPLOYED IN THE ARTS.

2019b. Drawing of a connecting motion as applied to double screw boats. *M. Chas. Bourdon, Paris.*

2019c. Model of Connecting Motion, joining the apparatus recommended in the Mulhouse manufactories.

M. Engel Dolfus, Paris.

This model belongs to the "Conservatoire des Arts et Métiers." Each apparatus of which it is composed has a special direction for its erection.

2019d. Papin's Steam Cylinder.

Royal Museum in Cassel (Director, Dr. Pinder).

The cast-iron cylinder was to have been a part of a large pumping engine, which, however, was never completed. The object was to supply a canal with water at the height of Hofgeismar, whereby the Landgraf Charles hoped to draw the traffic of the Weser to Cassel. An explosion which took place in Papin's laboratory while the Landgraf was contemplating a visit, led to the bold investigator withdrawing from the influence of his enemies. He came to England (1707), but did not succeed with his plans, and died in poverty. Papin's sketch of his contemplated pumping engine is exhibited with the cylinder. It was a peculiar combination of the Sayery engine and the piston engine recommended by Papin for other purposes. In the closed boiler A (with safety-valve of Papin's design), steam was generated, which (on opening the cock C) could pass through pipe B to cylinder D. Here it pressed down the close fitting piston or float E which rested on water that had been supplied through the funnel I from a reservoir. The water was thus forced into the chamber F; its return was prevented by a valve at H; and the steam-cock C being now shut and the condensed steam allowed to escape from the upper part of D, water from the reservoir was admitted anew, and the process repeated. The water raised into F could be further directed through the tube G. Papin proposed to add to the effect by introducing red hot irons through the opening in the cover of the cylinder D. Of the two cylinders it is probably D that it is exhibited.

2020. "A new Water Engine for **Quenching** and **Extinguishing Fires."**

Lent from the Patent Office Museum by the Commissioners of Patents.

This engine is made under patents No. 439, A.D. 1721, and No. 479, A.D. 1725, granted to Richard Newsham, pearl button maker, of London, and is one of the first engines in which two cylinders and an air vessel are combined and worked together so as to ensure the discharge of a continuous and uniform stream of water with great force. This invention of Newsham still exists in all fire-engines of the present day, with improvements in materials, workmanship, and the application of steam power.

2020a. Complete Working Model of the most Improved Form of London Brigade Steam Fire Engine, as now in daily use in the metropolis, constructed entirely by H. Nagy Effendi, Egyptian Government Pupil in the establishment of Shand, Mason, & Co. *Shand, Mason, & Co., London.*

2020b. Complete Working Model of the most Improved Form of London Brigade Manual Fire Engine, as in daily use in the metropolis. *Shand, Mason, & Co., London.*

2021. Machine for **Winding Cotton** into **Balls.** Invented by Sir Marc Isambard Brunel in 1802.

Lent from the Patent Office Museum by the Commissioners of Patents.

By the invention of this machine the use of cotton for sewing became universal, as before its invention linen thread or occasionally cotton, always in skeins, had been used.

2022. Model of **Machine** for **Carving Wood** and other **Materials.** Patented by Thomas Brown Jordan, A.D. 1845, February 17th, No. 10,523.

Lent from the Patent Office Museum by the Commissioners of Patents.

2025. The first **Machine** constructed for **Printing** and **Numbering Railway Tickets.** Invented and patented by Thomas Edmondson.

Lent from the Patent Office Museum by the Commissioners of Patents.

2031. Model of **Vauloue's Pile-driving Machine,** made by Jas. Ferguson, Esq., F.R.S. (the astronomer).

Bennet Woodcroft, Esq., F.R.S.

Vauloue's engine was used for driving the piles of old Westminster Bridge in 1739 and following years.

2113. Working Model of a steam pile-driving engine for submarine foundations, and other work. Sissons and White's patent. Sissons and White, Hull. *South Kensington Museum.*

Note.—This model, on about ½-inch scale, is a complete working illustration of a steam pile-driver. The winch to raise the monkey by an endless chain is driven by frictional gearing by the engine, which represents a high-pressure inverted-cylinder direct-acting engine, having slide valve, eccentric, flywheel, and force pump for feeding the boiler with water. The boiler represents an upright tubular boiler for working at high pressure.

2026. Model of **Large Shears.** Constructed by Messrs. Day & Co., of Southampton, for the Government Dockyards.

Lent from the Patent Office Museum by the Commissioners of Patents.

1980. Model of Dawes' and Holt's Hydraulic Shears.
In order to avoid buckling or bending either half of plate cut in two, a strip of metal equal to the thickness of the plate is sheared out of the plate, and the gap thus formed is utilized to allow the plate to pass the tie connecting the upper and lower blades; this machine can thus cut any size of plate.

Henry S. Holt, C.E., Leeds.

2027. Model of a **Hoist** or **Lift.** Patented by Thomas Silver in 1872. The principle of this invention is applicable to ascending gradients.

Lent from the Patent Office Museum by the Commissioners of Patents.

2027a. Model of Spout used in Sunderland Docks for loading vessels with coals.

River Wear Commissioners, Sunderland.

2027b. Model of Loading Drops used in Sunderland Docks for loading steam colliers with coals.

River Wear Commissioners, Sunderland.

2027c. Model of **Apparatus** for **raising Heavy Spherical Bodies.** *Bennet Woodcroft, Esq., F.R.S.*

2028. The **Original Traversing Lifting Jack.** Patented by George England in 1839.

Lent from the Patent Office Museum by the Commissioners of Patents.

2029. Four methods of **converting Rectilinear** into **Circular Motion.**

Lent from the Patent Office Museum by the Commissioners of Patents.

2030. Bar Lathe used by James Watt.

Bennet Woodcroft, Esq., F.R.S.

2030a. Circular Rest, for turning spheres nearly up to the full diameter of the lathe. The Rest being also adapted for holding all kinds of plain tools or the "drill," "universal," and "eccentric" "cutting frames," &c., with overhead motion.

Tyssen Amhurst.

2030b. Spherical Chuck (with six extra collars), for finishing spheres and chucking them for ornamental and other purposes. Invented by the exhibitor. *Tyssen Amhurst.*

2030c. Specimen in ivory turned by the above apparatus, consisting of a series of spheres detached one within the other, in Chinese fashion. *Tyssen Amhurst.*

2032. Instrument for **dividing** and **ruling** the **Brass Meridian Rings** of **Globes,** made by Jas. Ferguson, Esq., F.R.S. (the astronomer). *Bennet Woodcroft, Esq., F.R.S.*

2036a. Grover's Patent Holdfast Washers for securing nuts of fish bolts, and all bolts in machinery exposed to vibration. *T. W. Grover, C.E.*

2037. Photograph and Model representing an Hydraulic Canal Lift at Anderton, in Cheshire, constructed by Messrs. Emmerson, Murgatroyd, & Co., of Stockport and Liverpool, for the trustees of the River Weaver navigation, under the superintendence of Mr. Edwin Clark and Mr. Sidengham Duer.

This lift affords an easy and expeditious means of transferring laden barges between the Trent and Mersey Canal, and the River Weaver, instead of the tedious and costly process, previously in use, of transhipping goods from one set of barges to another. The canal is on the top of a bank, and the river is 50 feet 4 inches below it. Two barges can be transferred from the river to the canal, and two others from the canal to the river, in eight minutes; whereas in a chain of locks, where the difference of level is the same, only half that work can be performed in an hour and a half. It is pre-eminently useful wherever water is scarce, as it only takes about one per cent. of the water from the upper level which is used by the chain of locks. The photograph is from the work itself, while the model is only intended to show how one of the troughs, having taken a depth of 6 inches water over its area from the upper level, descends to the river, and in doing so lifts the other one nearly to the level of the canal by means of a central vertical hydraulic ram under each of the troughs. The rest of the operation is performed by a small steam engine. It was opened for public traffic by the trustees of the Weaver in July last, and has been in constant and successful operation since that time. The whole apparatus and other works in connexion with it are fully described by the exhibitor, and its applicability for lifting large ships is discussed in the "Minutes of the Proceedings of the Institution of Civil Engineers."

Sidengham Duer, B.Sc.

2038. Somerville's Machine for charging and drawing gas retorts by steam power.

It is constructed to run along the floor of retort house in front of retorts upon a line of rails or tramway, and consists of a platform on wheels, upon which is fixed a boiler and engine, which propels it and gives motion to the various parts. On the same platform is erected an upright frame, which serves as a support to the cradle or secondary platform carrying the scoop for charging or filling, and the rake for drawing the retorts; on top of frame is a receptacle (over the scoop) which is supplied with coals from another receptacle below by means of an elevator or Archimedean screw, whereby the scoop is filled with coals. The rake is attached in a similar manner to the scoop, and is propelled and withdrawn in the same way.

John Somerville, Dublin.

2039. Model of a **Californian Stamping Mill.**
Royal Saxon Mining Academy, Freiberg.

2041. Machine for **Engraving** duplicates of **Medallions, Sculpture, &c.** (J. Bates' Patent, 1823.)

Bennet Woodcroft, Esq., F.R.S.

The object of this machine is to copy or engrave on metal plates an exact representation of medals, sculpture, and other works of art executed in relief

2044. Model of **Nasmyth's Direct Action Steam Hammer.** (Nasmyth's Patent, 1842.)

Bennet Woodcroft, Esq., F.R.S.

2045. Drawing of a **50-ton Double-action Steam Hammer,** supplied to the Russian Government for their gun factory at St. Petersburg. *Thwaites and Carbutt.*

Diameter of cylinder, six feet six inches; length of stroke, twelve feet six inches; total height from ground line, fifty feet.

2045a. Model of a Friction-Hammer.

John Tille, Prague.

This model is 72 cm. high, 42 cm. broad, and 21 cm. in depth, and has been executed after the pattern of the friction-hammer constructed in the Royal Prussian Machine Workshops at Dirschau, where the exhibitor, in 1858 and 1859, was employed with the construction of the incline between Elbing and Osterrode.

With reference to this model it is to be observed that the small cog-wheels fixed on the revolving shafts of the friction-rollers have only been attached for the purpose of putting the model in motion with a crank.

2045b. Model of a Spring or Elastic Hammer.

John Tille, Prague.

These favourite spring-hammers, if in quick motion, effect a very powerful stroke; if in slow motion, a moderate stroke, the regulation of which is obtained by a treadle and a draw-pole, by means of a tension roller supported by levers. If the movement is stopped, the tension roller acts as a brake-weight.

In recent times, spring-hammers of this form are manufactured by Messrs. Auth, Fetn, and Deliege, at Liége.

2045c. Model of a Punching Machine, with contrivance of extramission. *John Tille, Prague.*

This model is constructed after Borsig's pattern, in which the balancing punch is moved forwards by a crank and wheels, by means of a movable press-bar.

2045d. Model of Parallel Shears. *John Tille, Prague.*

The movable cutting blade is fastened to a well regulated sliding piece, and moved by a crank and wheels by means of a draw-bar. This model is arranged at the same time to be worked by means of leather straps.

2045e. Model of Circular Shears, with cast ribbed frame.

John Tille, Prague.

2045f. Model of Circular Shears, with concave cast frame. *John Tille, Prague.*

These two models, the circular cutting blades of which are fastened on spindles, and put in motion by means of wheels and cranks, illustrate chiefly the solidity and elegance of the concave casting as compared with the ribbed casting.

2046. Circular Knitting Machine. (J. A. Tielen's Patent, 1842.) *Bennet Woodcroft, Esq., F.R.S.*

2047. Models of **Chinese Agricultural Implements** (9), small mill, &c. *Bennet Woodcroft, Esq., F.R.S.*

2048. Model for showing the **Curves** of **Screws.** *Bennet Woodcroft, Esq., F.R.S.*

2050. Traction Dynamometer, used for ascertaining the draught of carts, waggons, and all agricultural implements that are drawn by horses. Also, for determining the resistance of roads and streets. *Royal Agricultural Society of England.*

The instrument is harnessed just like a horse to the implement it is desired to test, and being itself drawn along by one or more horses it registers the total work done in passing over any given distance, the mean and extreme tractive force, the pressure on the back of the horse, and the lateral pressure in such implements as reaping and mowing machines. First used at Bedford, 1874. Designed and made for the society by its consulting engineers. *See* Journal of the Royal Agricultural Society of England, No. XX., part 2, page 678.

2051. Appold Friction Dynamometer, of 100 horse-power, used for measuring the work done by steam engines and other prime movers. *Royal Agricultural Society of England.*

The prime mover to be tested is coupled to the main shaft of the dynamometer, the friction breaks of which are loaded in proportion to the power it is desired to develop. The instrument registers the number of revolutions made in a given time, and this, together with the known weight on the breaks, furnishes the data for calculating the work done by the prime mover. This powerful instrument was constructed by the consulting engineers of the society, for the trial of steam ploughing and traction engines at Wolverhampton in 1871.

2053. Pneumatic Pump, with taps. Invented by 'sGravesande. *Professor Dr. P. L. Rijke, Leyden.*

The taps are at each stroke of the piston turned 90° by an appliance in the form of a cross fixed to the handle. (*See* 'sGravesande's "Physices Elementa Mathematica," ed. III. vol. II., p. 591.)

2053a. Pneumatic Intercepting Apparatus for sending and receiving message carriers in pneumatic despatch tubes of 3 inches diameter, to be worked on the circuit system. *Messrs. Siemens Brothers.*

2052. Diplograph. Writing machine for the **Blind,** by which writing in relief and ordinary writing are performed at the same time. *Ernest Recordon, Geneva.*

2054. Dr. Thursfield's Patent Writing Frame, for enabling the Blind, and persons with defective or failing sight, to write ; and for facilitating writing in darkness or an unsteady light. *Elliott Brothers.*

By means of Dr. Thursfield's apparatus anyone can write with equal facility in light and darkness. For those with defective or failing sight it is of the utmost value at all times, as when used in ordinary daylight no writing is visible, and the involuntary following of the writing by the eye is prevented. In cases of incipient cataract, and other ophthalmic diseases requiring rest, of after operations on the eye, it has been found a most valuable therapeutic agent. To literary men, travellers by railway or steamboat, and others compelled often to write in a bad or unsteady light, the invention will prove of great service. No ink or pencil is required, but the writing is equally legible and indelible. The mode of using the apparatus is very simple, and where any sight remains will at once be comprehended and found easy of execution.

2054a. Peters's Machine for Microscopic Writing, combining Ibbetson's Geometric Chuck. *Royal Microscopical Society, London.*

With this machine any combination of bicycloid curves can be produced on a scale wonderfully minute. Many beautiful and complex designs of this kind have been engraved on glass with remarkable precision, in the space of a circle the fiftieth of an inch in diameter.

A disc the one-hundredth of an inch in diameter appears to the unaided eye as a mere point, yet that point, not larger than the full-stop of ordinary print, will contain five circles each, the three-hundredth of an inch in diameter, and in a circle of that size (that is, about the size of a transverse section of a hair of the human head) the Lord's Prayer is written and can be read. It has also been legibly written in the three hundred and fifty-six thousandth part of an inch. In this specimen the writing is so small, that, in similar characters, the Bible and Testament together (said to contain 3,566,480 letters) could be written twenty-two times in the space of one English square inch.

The name and address of Mr. "Matthew Marshall, Bank of England," has been written in the two-and-a-half millionth part of a square inch.

2054b. Facsimile Drawing and Writing Apparatus. *G. F. Pichler, London.*

2055. Apparatus for filling **Manometer Tubes** with **Mercury** to any height.
The Director of the Physical Laboratory of the University of Groningen.

The end of an india-rubber tube is screwed into an opening in the base of the manometer. A wooden vessel filled with mercury is elevated by means of a vertical iron rod to a height nearly corresponding with that desired in the manometer tubes. With the aid of a piece of wood, which is plunged intc the wooden vessel, the exact adjustment of the mercury to the required height in the manometer can be effected.

2056. Diagrams illustrating the principles adopted in constructing **Wood-planing Machines.** These diagrams are used in lectures on Applied Mechanics at the I. and R. High School of Agriculture and Forestry, Vienna.

Dr. William Francis Exner, Vienna.

In the forestry section of the above school, series of lectures on the mechanical technology of wood-working are delivered annually. These are frequented by foresters who wish to become qualified for the post of manager of wood-working establishments. For these lectures diagrams of all sorts of tools and machinery for wood-working are prepared. The examples shown form only the first part of the series.

2057. Model of **Lever Plough, with 6 shares,** for ploughing by steam. (Fowler's system, reduced to one-tenth.)

M. Digeon, Paris.

2059. First Type-distributing Machine, invented by Alexander Mackie. *John Maclauchlan.*

2059a. Coining Machinery—A Cutting out or Punching Press, with self-acting feed and rollers for carrying the fillets.

Maudslay, Sons, and Field.

2060. Drawings of the air compressors on the Colladon system, employed in boring operations at the St. Gothard.

Professor Daniel Colladon, Geneva.

2061. Models, Twenty-seven, for teaching machinery, executed by M. Schröder, of Darmstadt. *Prof. Pigot, Dublin.*

Pumps.

2062. Model of Force Pump.

Prof. W. F. Barrett, Dublin.

2063. Model of Ordinary Water Pump.

Prof. W. F. Barrett, Dublin.

1989. Model of Sand Pump.

Council of King's College, London.

1989a. Air Water Pump, by Jagn.

R. Nippe, St. Petersburg.

2064. Model (to scale) **of Centrifugal Pump.**

Lawrence and Porter.

This pump has been patented by Messrs. Lawrence and Porter. The chief feature of the patent is the arrangement of making one side of the casing removable. The advantages of this system are as follows : By taking off the movable side, the disc or " fan " can readily be examined or removed in a few minutes without in any way disturbing or interfering with the suction or delivery pipes. This is found in practice to be a very great advantage.

Also by making the side removable the amount of both machine and hand work in fitting up the pumps is greatly reduced. The size and weight of any pump (to raise a given quantity of water) are considerably diminished, so that pumps made on this system are far more compact and portable than any centrifugal pumps of the ordinary construction.

One of Lawrence and Porter's pumps with discharge pipe six inches diameter, and weighing only $3\frac{1}{2}$ cwt., is capable of raising 900 gallons of water per minute, or 54,000 gallons of water per hour. Many of these pumps are now actually at work with highly satisfactory results, and they have received favourable notice by the scientific press.

N.B.—In the model the side can be removed by simply pulling it gently in a horizontal direction, as the nuts are merely for show, and do not hold it on, and by loosening the small screw in the pulley the disc and spindle can be instantly withdrawn for examination. The patentees will be glad to give further information.

2064a. Appold's Original Centrifugal Pump and Four trial Discs. *Council of King's College, London.*

2066. Archimedean Screw, with glass screw to show the raising of the water. *Elliott Brothers.*

2065. Hook's Universal Joint, by which a shaft can be kept in rotation at any angle. *Elliott Brothers.*

2067. Steam Thermometer, for testing temperature of steam in the supply pipes. *Elliott Brothers.*

It consists of a thermometer the bulb of which dips into an iron cup containing mercury and oil. By this means the bulb is protected from breakage by pressure, and the thermometer can be removed at any time without letting off steam.

2068. Air Bell.

The Committee, Royal Museum, Peel Park, Salford.

An apparatus consisting of a metal tube 30 feet long, with a percussion pump at one end and a clapper at the other, which rings a bell whenever the piston is struck.—[Supposed to be the invention of the late Mr. Gavin M'Murdock, of Soho, Birmingham.] Made by the late Richard Roberts, C.E., of Manchester, 1840.

2069. Parallel Motion.

The Committee, Royal Museum, Peel Park, Salford.

Consisting of one wheel revolving within another of double its size, and carrying a pin whose centre, coinciding with the pitch line of the lesser wheel, traverses a straight line equal to the diameter of the larger.—[The invention of the late Mr. James White, of Manchester.] 1842.

2073. Apparatus for supposed **Perpetual Motion,** used by Dr. Thomas Young. *The Royal Institution of Great Britain.*

A wheel supposed to be capable of producing a perpetual motion, the descending balls acting at a greater distance from the centre, but being fewer in number than the ascending ones. "Lectures on Natural Philosophy," by Thomas Young, M.D., 1807.

2074. Model of Parallel Motion, consisting of three parts only, which owing to the relative positions of the fixed centres and joints is not liable to lateral deviation in practice.

William Hayden.

2075. Parallel Motion; invented by the late Richard Roberts, C.E., Manchester; the peculiarity consists in the fixed centres being in the plane of the parallelism.

The Committee, Royal Museum, Peel Park, Salford.

2076. McKay's patent Equilibrium **Drilling Tools,** with specimens of work. *Menzies & Blagburn.*

This apparatus is designed to permit circular holes of any size to be bored out with mathematical accuracy and absolute precision as to their relative positions.

This object is attained by maintaining the centre point, around which the cutters revolve, immovably fixed during the process of boring, while the cutters are advanced, and are held in equilibrium with the centre points by a hydraulic medium contained within the chambers of the tool, the pressure being conveyed by the action of the feed given to the boring machine.

This apparatus is exhibited for the purpose of showing how accurate work can be obtained with a minimum of skilled labour and cost.

2076a. Isometric Drawing of an Expanding Mandril, or tool for fixing the tubes in the plates of boilers by expanding the ends so that the tubes are firmly fixed in their places.

W. H. Prosser.

Invented and made by the late Richard Prosser of Birmingham in 1845.

Two of these expanders were sent to the United States in 1847; an improvement on them is now being imported from that country.

2077. Bates' Anaglyptograph. Machine for producing drawings or etchings in relief from models, coins, medals, &c.

George Hogarth Makins.

The machine consists of two portions:—The first a solidly framed oblong base, in which is fixed a long double screw, right-handed at one and left-handed at the other half, and of 20 threads per inch; rotation of this gives opposite motion to two tables, upon the front one of which the object to be copied is fixed, and upon the other the plate to receive the etching or drawing. At the winch end of the screw is fixed a wheel cut with 100 teeth, and also a stop arrangement by which any number of the teeth can be taken, and thus equal partial turns given to the screw.

The second portion of the machine is a framed apparatus carrying the tracing and etching points. This is provided with wheels for travelling across the base, and a groove is formed in the latter for their direction. The tracing point is attached to a bar which in rising does so at an angle of 45°. In the centre of the bar is a piece which, being between friction wheels attached to the diamond or etching point frame, will, as the bar rises by passing over any elevation in the object, cause the diamond frame to move at right angles to the motion of the machine, and thus the line forming is curved or waved just in proportion to the height of the elevation passed over; hence the appearance of relief given to the etching.

2078. Model of a **Steam-boiler** to show Herschel's boiler arrangement. *Bock and Handrick, Dresden.*

2079. Model of **Valve Motion,** to show the link motion of Stephenson, Gooch, and Allan. *Bock and Handrick, Dresden.*

2080. Drawing of a **Model** for **testing** the **Link Motions** of Stephenson, Gooch, and Allan, for locomotive manufactories. Greatly improved and quite new construction.
Bock and Handrick, Dresden.

2081. Model, for the demonstration of **Centroids.**
Bock and Handrick, Dresden.

2082. Model of a **higher pair** of **Elements.**
Bock and Handrick, Dresden.

2083. Vierkurbelkette. (Four crank-chains.)
Bock and Handrick, Dresden.

2083a. Slider Crank Chain.
Bock and Handrick, Dresden.

2083b. Mechanism of Slider Crank Chain.
Bock and Handrick, Dresden.

2084. Model of a **Hanger.** *Bock and Handrick, Dresden.*

2085. Model of a **Wall Bracket.**
Bock and Handrick, Dresden.

2086. Model of a **Pedestal.** *Bock and Handrick, Dresden.*

2087. Three Models of **connecting Rod-ends.**
Bock and Handrick, Dresden.

2088. Two Models of **rivetted Joints** for **Boiler Plates,** to take to pieces. *Bock and Handrick, Dresden.*

2089. Model of a **Double-beat Valve.**
Bock and Handrick, Dresden.

2090. Model of a **Throttle Valve.**
Bock and Handrick, Dresden.

2091. Model of a **Cup Valve.**
Bock and Handrick, Dresden.

2094. Drawing Instruments and Scales.
Bock and Handrick, Dresden.

2095. Tachometer with registering apparatus, after Dr. Pröll. *Bock and Handrick, Dresden.*

2095a. Printing Machinery. This model of an ordinary printing machine illustrates the inventions of Edward Cowper in 1818, and Augustus Applegarth in 1823, as applied to the printing of books, newspapers, &c., which had up to that time been commonly printed at hand presses.

The distribution of the ink transversely as well as longitudinally removed the difficulties previously felt, and gave perfect distribution, and consequently good printing. *Edward Alfred Cowper.*

2096. Model of Cowper's Cylinder Printing Machine.
Council of King's College, London.

2058. First Type-composing Machine, invented by Alexander Mackie.
John Maclauchlan, Dundee Free Library and Museum.

Mr. Mackie's Type-composing Machine, of which this is the germ, is used in offices of some of the London daily newspapers, and various books have been printed by its aid.

2058a. Type Composing Machine. *John Walter, M.P.*

2058b. Type Casting Machine, distribution being dispensed with. *John Walter, M.P.*

2097. Model of Revolving Screw, with Apparatus illustrative of the Inclined Plane. *Council of King's College, London.*

2099. Working Model of a patent silk throwing machine. Thomas Dickens, Edgemoor House, Higher Broughton, Manchester. *South Kensington Museum.*

Note.—The bobbin, flyer, and reel are driven by friction gear, which secures steady and certain action.

2100. Working Model of a strand-making machine for machine cotton rope; with a 49 reel frame for cotton yarn. Henry Cotton. *South Kensington Museum.*

2101. Model, on a $\frac{1}{3}$rd size, of a pirn winding machine. For making weaver's bobbins from cotton hanks. Robert Hall, Hope Foundry, Bury. *South Kensington Museum.*

2102. Model, on a $\frac{1}{3}$rd size, of a drum winding machine. For making warper's bobbins from cotton hanks. Robert Hall, Hope Foundry, Bury. *South Kensington Museum.*

2104. Model of power weaving loom by George White, Glasgow, 1830. *South Kensington Museum.*

The shuttle in this loom is arranged with a peculiar even power movement, by which, for the propulsion of the shuttle, one uniform power is exerted, thereby enabling fine fabrics, such as cambrics, lawns, faconets, &c., to be manufactured.

2105. Model of a power weaving loom, showing arrangement for working a double shuttle-box, and other features. Designed about 1840. *South Kensington Museum.*

2106. Model of power weaving loom, with Jacquard arrangement attached, for weaving or working figured stuffs or pattern stuffs. *South Kensington Museum.*

This model shows the arrangement of the cards in the loom after they have been cut for the desired pattern to be worked. It further illustrates the general movement of the several parts of a Jacquard loom.

2106a. Model of **Power Loom** constructed to show the ordinary manner of working the Beam and Taylor's patent method of performing the same.
Lent from the Patent Office Museum by the Commissioners of Patents.

2106b. Improved Jacquard Apparatus and **Fittings,** worked by pegs. *Bennet Woodcroft, Esq., F.R.S.*

In this improved Jacquard apparatus, those warp threads which are not raised to form the shed or opening for the shuttle to pass through and deposit a weft thread are depressed to the same extent that the others are raised. (Woodcroft's Patent, 1838.)

2106c. Full-size **Section Tappet** for **Looms,** for weaving a variety of patterns. *Bennet Woodcroft, Esq., F.R.S.*

2106d. Model of **Loom,** with improved tappet plates and jacquard apparatus. (Woodcroft's Patent, 1838.)
Bennet Woodcroft, Esq., F.R.S.

2106e. Mule for **Spinning Cotton** and other fibrous substances. (Jas. Smith's Patent, 1833.)
Bennet Woodcroft, Esq., F.R.S.

2106f. Improved Jacquard Machine worked by paper cards. *Bennet Woodcroft, Esq., F.R.S.*

The improvement in the jacquard machine consists in its being so constructed and worked as to depress some of the warp threads as much as it elevates others, whereas in the machine invented by Jacquard, and called after him, none of the warp threads were depressed, the opening for the shuttle being made by elevating some of the warp threads only. (B. Woodcroft's Patent, 1838.)

2106g. Steam Power-loom. *Bennet Woodcroft, Esq., F.R.S.*

2107. Model of a hand loom, for weaving sacks, hop pockets, &c. This loom is designed to weave sacks or pockets without a seam either at the sides or end. Invented by T. Clulow.
South Kensington Museum.

2108. Model of a hand loom for weaving fishing nets. G. Roberts, inventor. *South Kensington Museum.*

2109. Model, on a $\frac{1}{3}$rd scale, of a plain and fancy goods weaving loom, having 12-inch reed space. The model can be driven either by hand or power. Robert Hall, Bury, Lancashire.
South Kensington Museum.

2110. Model, on $\frac{1}{3}$rd scale, of a plain and fancy goods weaving loom, having 12-inch reed space. The model is arranged to be driven by power. Savill and Woolstenhulme, machine makers, Oldham. *South Kensington Museum.*

2111. Series of Temples (20 in number), of various sizes. Used in power looms for stretching the woven cloth. The temples are self-acting, and are suitable for woollen, cotton, and other heavy or light fabrics. R. Hall, Hope Foundry, Bury, Lancashire. *South Kensington Museum.*

2112. Drawing of patent machinery for preparing chemically pulp from wood, straw, and fibrous material for the manufacture of paper of all kinds and qualities. Sinclair's system. J. McNicol, C.E., 97, Buchanan Street, Glasgow.
South Kensington Museum.

Note.—The drawing represents the following portions of the patent machinery by W. Sinclair, for paper manufacture.

On a $\frac{1}{2}$-inch to 1 foot scale :—

Fig. 1. Longitudinal through section of Sinclair's patent high-pressure tubular steam boiler.

Fig. 2. Front or firing end elevation of Sinclair's high-pressure tubular steam boiler.

Fig. 3. Sectional elevation of wood-pulp boiler.

Fig. 4. End elevation of blow-off pulp receiving tank.

Fig. 5. General plan of apparatus.

Fig. 6. Front and side elevation of wood-chopping machine.

Fig. 7. On a scale of $\frac{1}{4}$ inch to 1 foot. The soda ash (used to dissolve the wood into pulp) recovery apparatus. A longitudinal and cross section of the apparatus.

Fig. 8. On a full size scale. The Sinclair's patent conical plug joint for high-pressure steam boiler tubes.

Fig. 9. On a full size scale. The section of a hollow conical boiler tube joint. Sinclair's system.

2114. Working Drawing, on a $\frac{1}{3}$ scale, or 4 inches to 1 foot.

Sheave or pulley. For a hoisting crane.

Side and end elevations.

Two through sections.

South Kensington Museum.

2115. Working Drawing, on a $\frac{1}{2}$ size scale, or 6 inches to 1 foot.

Spur wheel. Tooth wheel for gearing.

Side elevation, showing method of laying out pitch of tooth and tooth circle.

Section of arm of wheel.

Section through centre of wheel.
Plan of wheel. *South Kensington Museum.*

2116. Working Drawing, on a $\frac{1}{3}$ scale, or 4 inches to 1 foot. Mitre wheel, gear wheel. Showing plan, elevation, and sections of wheel.

South Kensington Museum.

2117. Working Drawing, on $\frac{1}{12}$ scale, or 1 inch to 1 foot.
Eight feet cast-iron fly-wheel.
Side elevation with part of rim in section.
End elevation. Three through sections.

South Kensington Museum.

Note.—The wheel is cast in two segments, and united by wrought-iron hoops, shrunk on the boss, and by dowels and cotters at the rim.

2118. Working Drawing, on a $\frac{1}{4}$ scale, or 3 inches to 1 foot.
Cast-iron engine crank.
Side elevation. Plan throughout.
Plan when turned $\frac{1}{4}$ of a revolution.
Section through firm and web.
A longitudinal through section, and a section when turned $\frac{1}{4}$ of a revolution.

South Kensington Museum.

2119. Working Drawing, on a $\frac{1}{3}$ scale, or 4 inches to 1 foot.
Connecting rod end, for a 25 horse-power steam engine.
Elevation. Plan. Two sections.

South Kensington Museum.

2120. Working Drawing, of the governor of a steam engine.
Front and side elevation.
Elevation and plan of slide.
Pendulum rod, showing ball in section, and method of attachment.
Elevation and plan of forked rod.
Section through slide.
The front and side elevations are on $\frac{1}{4}$ scale, or 3 inches to 1 foot.
The details are on $\frac{1}{2}$ scale, or 6 inches to 1 foot.

South Kensington Museum.

2121. Working Drawing, on a $\frac{1}{2}$ scale, or 6 inches to 1 foot.
Pillar block, plummer block, or pedestal; for a $4\frac{1}{2}$-inch shaft or journal.
Side elevation.
End elevation. Plan. Sheet No. 1.

South Kensington Museum.

2122. Working Drawing, on a $\frac{1}{2}$ scale, or 6 inches to 1 foot. Pillar or plummer block for a $4\frac{1}{4}$-inch shaft or journal.
Various sections. Sheet 2.
South Kensington Museum.

2123. Working Drawing, on a $\frac{1}{4}$ scale, or 3 inches to 1 foot. Hanging bracket and pillar block, for a $3\frac{1}{2}$-inch shaft; attached to a 16-inch cast-iron girder.
Front and side elevations. *South Kensington Museum.*

2124. Working Drawing, full size: Steam whistle.
Elevation. Plan. Sections.
The vertical section shows by arrows the passage of the steam through the whistle.
South Kensington Museum.

2125. Working Drawing, on a $\frac{1}{4}$ scale, or 3 inches to 1 foot. Movable head stock for a turning lathe.
Side elevation, plan, and section.
End elevation and section.
South Kensington Museum.

2126. Working Drawing, full size.
Water cock or tap.
Side elevation. End elevation.
Plan. Side and end elevation of plug.
Through section of tap.
South Kensington Museum.

2127. Working Drawing, on a $\frac{2}{3}$ scale, or 8 inches to 1 foot. Stop-cock or straightway cock, for steam or water.
End elevation. Side elevation. Plan. Two sections.
Fourteen working drawings (lithographs), parts of machinery and steam engines. Thomas Busbridge, Plumstead, S.E.
South Kensington Museum.

2127a. Machine for Originating Screws, with micrometer adjustment applied to tangent screw which sets the guide at any angle suitable to required pitch (adjustable to $\frac{1}{100}$ degree). The cutter is carried in sliding rest. Specimens of screws originated in machine. *Maudslay, Sons, and Field.*

2127aa. Machine for Originating Screws of any required pitch and diameter (by the late Mr. Henry Maudslay).
Maudslay, Sons, and Field.

Inside the cylindrical hole (below the table) is a steel knife edge which is attached to the divided circle (above). This circle and knife edge can be adjusted by a micrometer tangent screw to the calculated angle of the thread. The knife edge presses on and acts as a guide to a cylindrical rod passed through the

hole, and gives the required feed while the thread is cut by a small tool carried in the slide rest seen at the side of the machine. The bar on which the screw is to be cut is carried in the centres of a lathe, while the screw machine is allowed to travel freely along the bed of the lathe. The bar is removed from the machine so as to enable the knife edge inside to be seen. When the circle and knife edge are set at the required angle they can be clamped to the frame. Date 1800–1805.

2127b. Three Guide Screws originated in the above machine; each screw contains 50 threads to the inch. The largest screw is $1\frac{1}{32}$ in. diameter and has 3,144 threads in the entire length. The nut for this screw is shown by its side; it is 12 inches long and has 600 threads. *Maudslay, Sons, and Field.*

2127c. Hand Plane for Metal, by the late Mr. Henry Maudslay. *Maudslay, Sons, and Field.*

2127d. A Metal Plough for Moulding, by the late Henry Maudslay. *Maudslay, Sons, and Field.*

2127f. Original Screw Cutting Lathe, made and used by the late Henry Maudslay. It has 28 change wheels, and sector frame for carrying an intermediate wheel for cutting left hand screws. Four guide screws are shown, 100 threads, 50 threads, 35 threads, 30 threads to the inch. Also a small cone chuck and hollow mandril, screw tools for slide rest, and the original working handle used by Mr. Maudslay, below the bed. Date 1800 to 1810.
Maudslay, Sons, and Field.

2127g. Skeleton Stocks and Dies, four sets, about 1805 to 1810, made and used by the late Henry Maudslay. The extreme delicacy and finish of the work are worthy of notice.
Maudslay, Sons, and Field.

2127h. Coining Machinery. A cutting-out press for blanks, with self-acting feed rolls to deliver fillet. Date about 1814.
Maudslay, Sons, and Field.

2135. Three Elliptical Guides.
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

2138. Elliptic Guide, with long radius bar.
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

2139. Approximate Elliptic Guide.
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

2140. Spur Wheel Gearing.
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

2142. Kinematic Pillar Vice, with triangular link-motion.
Royal Geological Institute and Mining Academy (*Director, Prof. Hauchecorne*), *Berlin.*

This stand is so arranged that any link of the kinematic chains can be fastened in it easily and securely, so that they can be shown in every possible position.

Wheel Gearing.

2143a. Model of a Machine for Cutting the Teeth of Bevel Wheels. *F. Engel, Hamburg.*

In the usual cutting and planing machines for conical toothed wheels, each interstice between the teeth is produced by at least two operations; first one side of a tooth is shaped and planed, then the opposite side of the next tooth. The present machine cuts both profiles simultaneously with the same cutter. A lateral motion is communicated to the cutter, the axis of the tool oscillating about the cutting point of the conical surface, and working alternately the one and the other side of the tooth profile. The machine is more accurate than previous ones, and other kinds of wheel can be shaped with it.

2143b. Samples of Wheels which have been cut by the Machine. *F. Engel, Hamburg.*

2143c. Drawing of the Machine. *F. Engel, Hamburg.*

2144. Bevel-Wheel Gearing.
Royal Geological Institute and Mining Academy (*Director, Prof. Hauchecorne*), *Berlin.*

The models exhibited are a small portion of the collection used for machine-instruction in the Königlichen Berg-Akademie (Royal School of Mines). They have been made specially for this purpose by Herr Maiss, in the workshops of he Academy, upon the designs of Prof. Hörmann. The models of separate mechanisms have been constructed upon the principles laid down in Prof. Reuleaux's "Theoretische Kinematik"; they are all arranged for "inversion," that is, so that either of their links may be fixed in the screw stand exhibited with them, and the various properties and applications of the inversions easily shown.

The models are all made with the special view of illustrating in the most complete, clear, and simple manner the principles of the machines and mechanisms which they represent. All details not required in this relation are omitted or made subordinate, the parts which it is important for the students to observe are polished, the other parts, in order not to attract attention unnecessarily, are made a dead black, so that all disturbing reflections of the light are prevented. Care has been taken also to arrange them so that all essential parts and their combinations may be visible at a glance in all parts of the class-room, so that the alterations which it is necessary to make during the lectures may occupy a minimum of time, and altogether that teachers may find their use in demonstrations very convenient. In the steam-engine models it has also been endeavoured to make the relative dimensions and arrangements as far as possible to resemble those of actual practice.

2144a. A Pair of Worm Wheels, with parallel axes.
Royal Geological Institute and Mining Academy (*Director, Prof. Hauchecorne*), *Berlin.*

2144b. Worm-Wheel, with inclined teeth.
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

2144c. Annular Wheel and Pinion.
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

2144d. Hypocycloidal Gearing.
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

2144e. Worm-Wheel, with straight teeth.
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

2144f. Pair of Worm Wheels, with axes at right angles.
Royal Geological Institute and Mining Academy (Director, Prof. Hauchecorne), Berlin.

2144g. Skew Mitres.
The Committee, Royal Museum, Peel Park, Salford.

A pair of toothed mitre wheels mounted on shafts that cross each other. The invention of the late R. Roberts, C.E., of Manchester, 1836.

2144h. Intermittent Wheels.
The Committee, Royal Museum, Peel Park, Salford.

The larger wheel performs six revolutions for one of the lesser. The invention of the late R. Roberts, C.E., of Manchester.

2145. Model of Cugnot's Steam Carriage, 1783.
Conservatoire des Arts et Métiers, Paris.

2146. Model of a centrifugal smoke purifier.
Dr. Otto Braun, Berlin.

This model shows the action of centrifugal force on bodies suspended in gases, by means of it sparks, soot, tar, ammonia, &c. can be removed from smoke.

2146a. Tyndall's Smoke Filter Respirator, suitable for firemen, fire-escape men, and for persons entering deleterious atmospheres. *James Sinclair.*

The filtration is by means of dry cotton wool, dipped in glycerine and charcoal.

2146b. Tyndall's Smoke Filter Respirator, combined with elastic tube, suitable for mining operations, chemical works, breweries, &c. *James Sinclair.*

This respirator is designed to enable the wearer to enter and breathe freely in mephitic gases by means of the tube, which can be used in lengths up to 90 feet, the wearer being enabled to communicate verbally with those outside and they with him.

VII.—SHIPPING, NAVAL ARCHITECTURE, AND MARINE ENGINEERING.

2147. Models made of hard paraffin for ascertaining the **Resistance** of **Ships** by measuring the resistance of their models.
W. Froude, F.R.S.

The models from 6 to 16 feet in length are made of hard paraffin. The experimental apparatus employed in working the model includes appliances for designing, moulding, and casting the models, shaping them by automatic machinery, moving them through the water at the required speeds, and automatically recording the leading phenomena of the trial, namely, the speed, the resistance, and the change of level induced by the speed at each end of the model.

The several processes are illustrated by the accompanying series of seven photographs and two specimens, which may be explained as follows:—

No. 1. The designer.

This consists of a pile of adjustable templates, the thicknesses of which represent the horizontal intervals between the successive water-lines of the intended models shown on a reduced scale. One edge of each template is an elastic steel band held to a wooden base-piece by adjustable ordinates hinged to the band and sliding through mortices in the base-piece fitted with hinged metal clamps. One of these templates (No. 8) set up as for use is sent to aid this explanation.

The photograph shows them in combination, and represents the intended small scale model by a series of water-lines in steps, which, if either filled up solid and fair to the salient angle of each, or trimmed off fair to the re-entering angle, would constitute the finished form.

No. 2. *a*. The moulding box; *b*. The mould; and *c*. The core.

L. B. D.
a. A rectangular wooden box 16′ × 2′ 9″ × 1′ 10″.

In this the external form of the full sized model (that is (*b*) the mould) is shaped by help of a series of rough cross sections deduced from the small scale designer, and into the mould is fitted the core (*c*), which constitutes the figure of the inside of the model. *c* is framed on a series of internal cross sections made good to a surface and rendered coherent, first by a series of laths nailed to them externally, and, secondly, by a skin of calico drawn tight over the lathed surface, and then coated with plaster-of-paris and clay. Between this "core" and the "mould" there is, of course, a space, equal to the intended thickness of the model, into which space the melted paraffin is run, and there allowed to remain until by cooling it has become solid enough to bear removal.

Nos. 3 and 4, the shaping machine.

This is what has sometimes been termed in technical phrase a "copying machine." The model, bottom upwards, and adjusted successively to a series of different levels, travels longitudinally between a pair of revolving cutters, which are caused by means of a hand lever to so recede and approach one another, as the model passes, as to cut upon the model the horizontal section or "water-line," correctly appropriate to the level at which the model is set. At the side of the machine, in full view of the operator, there is a vertical board, which carries either a drawing of the intended model, showing the series of water-lines to be cut, or one of the "designer" templates already described. In front of this board is a "tracer," and the board and the "tracer" severally imitate upon the appropriate scales (the former by longitudinal motion, the latter by vertical motion) the longitudinal motion of the model and the lateral motion of the cutters. Thus the drawing (or template) passing along beneath the tracer is practically a small scale picture of the model travelling past the

cutters, and if the tracer be made to follow the correct line on the drawing (or to follow the edge of the template) the revolving cutters will cut the correct water-line on the model.

The model is then finished by hand with spokeshaves and scrapers, an operation which takes a man about three hours.

No. 5. The hauling engine.

This is the instrument by which the required motion through the water at definite speed is given to the model. The dynamometric truck to which the model is attached is connected by a wire rope with a winding drum, driven by a small stationary double-cylinder steam engine. The engine is regulated by an extremely sensitive governor, acting upon a delicate steam throttle valve, on what is known as the "differential" principle, in which the governor rotates at its own appropriate speed, independently of the engine, the steam valve being opened or closed according as the engine is lagging behind the governor or overtaking it.

By adjusting the centrifugal weights of the governor, with a right and left-handed screw, and by differently speeding the belt which connects it with the engine, any required speed may be assigned to the engine between the limits of about 150 and 350 revolutions per minute, and by further changing the gear wheels connecting the engine and winding drum, speeds varying from 60 to 1,200 feet per minute may be assigned to the dynamometric truck.

Nos. 6 and 7. The dynamometric truck with model under it.

The dynamometric truck runs on a straight and level railway about 200 feet in length, suspended over a waterway 36 feet wide and 10 feet deep. The model floating in the water is as it were "harnessed" to the truck, and travels with it. It is kept from diverging sideways by a knee-jointed frame or "guider" at each end, of such construction as to perfectly prevent the slightest sideways deviation of the model, but in no way to interfere with its rising or falling, or moving in a fore and aft direction with reference to the truck. The towing strain (*i.e.*, the force necessary to make the model accompany the truck in its longitudinal progress) is taken during the experiment by a spiral spring, the extension of which, measuring the towing force, is indicated on a large scale (through the intervention of certain levers) by a pen which makes a line on a recording cylinder covered with a sheet of paper. The recording cylinder is driven by the truck wheels, and thus its circumferential travel indicates distance run; at the same time another pen, jerked at half second intervals by a clock, records time. Other pens actuated by strings led over pulleys, record the change of level of the ends of the model. Thus the diagrams made furnish an exact measure of the speed, and a continuous record of the resistances and of the change of level of the model throughout the experimental run at steady speed. While starting or stopping, the model is controlled by hand levers to prevent the dynamometric spring being over-strained.

No. 8. A "designer" template.

This consists of one of the pile of adjustable templates shown in photograph No. 1, and already described.

No. 9. A segment of a model.

This specimen segment of a model is partly in a finished condition and partly in the condition in which it is left by the shaping machine, Nos. 3 and 4. It thus shows the series of water-line cuts made by the machine, and a part of the original cast surface remaining between the cuts.

2147aa. Model of the solid of **"Least Resistance,"** by the late Andrew John Robertson, dated 1861.

Michael Scott, London.

2147ab. Model of the Steam Ship **"Sir John Lawrence,"** embodying to a considerable extent the form of least resistance, designed by Michael Scott, in conjunction with the late Andrew John Robertson. The performance of this ship was excellent.
Michael Scott, London.

2147ac. Three diagrams of a new type of **War Ship,** designed by Michael Scott in 1869, and published in 1870.
Michael Scott, London.

In this design the surface exposed to hostile fire is diminished by constructing the vessel with a central fort, armour plated all round, an armoured deck under water, and dividing the space above this armoured deck for a height of six feet into water-tight compartments, which would be filled with fuel or water when going into action. She is intended to carry both turret and broadside guns, and might be armed with a submarine weapon.

2147ad. Three diagrams of new type of **War Ships,** designed by Michael Scott in 1870, and published in 1871.
Michael Scott, London.

In this design there is a central fort, armour plated all round; an armoured deck under water sloping downwards towards the bow, so as to prevent the vessel from being raked in a seaway, and strengthening the ramming beak. The ship is intended to carry sail, her turrets to be placed abreast, and also to carry broadside guns.

Some of the most important features in these designs have been adopted in the most modern war ships.

2147a. Model of Bermudian Sailing Boat "Pearl."
William Moody.

2147b. Model showing the method of framing a screw aperture of a line-of-battle ship, to enable the screw or propeller to be raised or lowered at pleasure. *William Moody.*

2147c. Model of a midship section of a first-rate, showing the method of framing a ship. *William Moody.*

2147d. Model of the State Barge in which William III. landed at Greenwich, 1689. *William Moody.*

2147e. Model of Bow of a first-rate. *William Moody.*

2147f. Bow of a First-rate showing the disposition of the frame timbers and hawse pieces. *William Moody.*

2147g. Stem of a 50 gun Frigate showing the disposition of the stem timbers. *William Moody.*

2147h. Stem of a 50 gun Frigate showing the disposition of the stem timbers. *William Moody.*

2147k. Jury Rudder as fitted to the "Intrepid," Arctic discovery vessel. *William Moody.*

2147l. Stem of a First-rate showing the disposition of the frame and stern timbers. *William Moody.*

2148. Model of the first steamer **"Comet,"** built in 1811 by John Wood, senior partner of John Reid and Co., Port Glasgow, Henry Bell, engineer.

John Reid and Co., Engineers and Shipbuilders, Port Glasgow.

Dimensions, 40 feet × 10 feet 6 inches × 4 feet. Power of 3 horses. Plied between Greenock and Glasgow.

2148a. The **Original Engine** of **Henry Bell's Steamboat "Comet,"** which was the first steamboat in Europe advertised for the conveyance of passengers and goods.

Lent from the Patent Office Museum by the Commissioners of Patents.

The engine was made and fitted on board the "Comet" in 1812.

2148b. Drawing of the "Elizabeth," built by Charles Baird in 1815, and run on the Neva.

George Baird, St. Petersburg.

She was constructed out of a barge, and the chimney was of brick. The floats of the paddle-wheels were kept in a vertical position by means of shafts and mitre wheels. Scale of drawing, ¼ inch to the foot.

2148c. Drawing of Paddle-wheel Steamer, built by Charles Baird in 1817, to carry passengers between Petersburg and Cronstadt, showing end view, longitudinal view, plan, and longitudinal section. *George Baird, St. Petersburg.*

A. Steam engine.
B. Boiler.
C. C. Crank shafts on either side, with fly-wheel.
D. D. Toothed wheels driving paddle-wheels.
E. E. Paddle-wheels with floats revolving 50 turns per minute, by which the vessel is propelled.
F. Funnel leading from furnace serving in place of a mast.
G. G. Fore and aft cabins.
H. H. Side decks, to protect the wheels from the blows of the waves.
I. I. Paddle-boxes.
K. L. Staircase and rudder.
Scale of drawing, ¼″ to 1 foot.

2148d. Model of Screw Propeller, driven by a pair of engines direct acting, having sun and planet motion at crank, so as to give the propeller two revolutions for every revolution of the engine.

Glasgow Mechanics' Institution.

2148e. Model of Iron Floating Dock, built by Messrs. Randolph Elder and Co. (now John Elder and Co.), Glasgow, and erected at Saigon, Cochin China, for the French Government.

Messrs. John Elder and Co.

Dimensions: length, 300 feet; breadth, 94 feet; depth, 42 feet.

Capabilities: will lift a vessel of 4,800 tons weight, drawing 27 feet of water. Weight of dock, 2,800 tons.

2148f. Picture of the "Great Western" steamship, the first steamer that traded regularly between England and America. Date 1838. *Maudslay, Sons, and Field, Engineers, Lambeth.*

2148g. A table of the first 50 Voyages of the "Great Western" steamship.
Maudslay, Sons, and Field, Engineers, Lambeth.

2148h. Model of the sailing ship **"Cairnsmore,"** length 223 ft., breadth 33 ft. 6 in., depth 20 ft. 6 in.; tonnage, O.M. 1211. Built by John Reid and Co., Port Glasgow, for Messrs. Nicholson and McGill, Liverpool, 1854. *John Reid and Co.*

This ship made her first passage from Clyde to Bombay in 65 days.

2149. Model of a **Direct-acting Marine Steam Engine.** Patented by J. Miller, A.D. 1841, No. 9,107.
Lent from the Patent Office Museum by the Commissioners of Patents.

2150. Parent Steam Engine, made for Patrick Miller, Esq., and used by him on the lake at Dalswinton, 1788.
Bennet Woodcroft, Esq., F.R.S.

For some years prior to 1787 Patrick Miller, Esq., of Dalswinton, Scotland, had been engaged in a series of experiments with double and triple vessels propelled by paddle-wheels, worked by manual labour. In the experimental trips of 1786 and 1787 he was assisted by Mr. James Taylor (the tutor to his younger sons), and at the suggestion of the latter it was determined to substitute steam power for manual labour. For this purpose, in the early part of 1788, Taylor introduced William Symington, an engineer at Wanlockhead Lead Mines, who had previously obtained letters patent (June 5, 1787, No. 1,610) for "his new invented steam engine on principles 'entirely new.'"

An arrangement was made with Symington to apply an engine, constructed according to his invention, to one of Mr. Miller's vessels, and consequently the engine which forms the subject of this notice was made, the castings being executed in brass by George Watt, founder, of Low Calton, Edinburgh, in 1788. At the beginning of October in that year the engine, mounted in a frame, was placed upon the deck of a double pleasure boat, 25 ft. long by 7 ft., and connected with two paddle-wheels, one forward and the other abaft the engine, in the space between the two hulls of the double boat. On the steam being put in action it propelled the vessel along Dalswinton Lake at the rate of 5 miles an hour.

2151. Photograph of a water-wheel with paddles, floating by itself, and capable of being utilised on streams and navigable rivers. *Professor Daniel Colladon, Geneva.*

A wheel on the above system has been at work for the last ten years on the Rhone near Geneva, with satisfactory results.

2152. Model, on a scale of 1½-inches to 1-foot, of the horizontal condensing screw engines of H.M.'s Turret ship "Monarch,'

8,164 tons. Built, 1868. 1,100 horse-power, nominal. Lent by Humphrys and Tennant, Engineers, Deptford.

South Kensington Museum.

Note.—The engines of H.M.S. "Monarch" were designed and built in 1868 by the lenders of the model. Their indicated horse-power is 6,600 horses. The engines make 60 revolutions per minute, and are on the direct-acting principle, with return connecting rods, and have surface condensers. There are four piston rods to each engine piston. The cylinders are 120 inches in diameter, having a stroke of 4 feet 6 inches.

The condensers are of wrought iron, their tops being of cast brass. They can be used either as surface or jet condensers. They contain 17,264 copper tubes, each 6 feet long, giving large condensing surface per nominal horse-power. The water is driven through the condensers passing outside the tubes, by a reciprocating pump, the inlet and outlet pipes being of ample diameter.

The cylinders of the engines are steam jacketed.

The crank shaft is 22 inches in diameter, and the propeller shaft 18 inches.

The starting, stopping, and reversing gear is placed on a central platform between the cylinders and condensers of the engines.

The crossheads to piston rods are forged solid; their guides have very large surfaces; they are easily adjusted.

The boilers are tubular, having brass tubes. They contain 21,000 square feet of heating surface, and about 770 square feet of grate surface.

The ship's propeller is a two-bladed Griffith screw, of gun-metal; 23 feet 6 inches diameter, with adjustable pitch from 23 feet 6 inches to 28 feet 6 inches. The propeller weighs 22 tons.

2153. Model, on a scale of 1 inch to 1 foot, of the horizontal condensing screw engines of H.M.'s turret ship "Prince Albert," 2,529 tons. Built, 1860. 500 horse-power, nominal. Humphrys and Tennant, Engineers, Deptford. *South Kensington Museum.*

Note.—The "Prince Albert" was built in 1864 by Messrs. Samuda. She is an armour-plated turret ship, 240 ft. in length, 48 ft. beam, 25 ft. 3 inches in depth. She is driven by engines, of which the model is a representation, and fitted with a four-bladed screw propeller.

2153a. Whole Model, an iron floating dock built for the French Government by Messrs. Randolph, Elder, and Co., Glasgow, Port Saigon, Cochin China. *John Elder and Co.*

Dimensions of the dock:—Length 300 feet, breadth 94 feet, depth 42 feet. Weight of dock, 2,800 tons.

The dock will lift a ship of 4,800 tons weight, drawing 27 feet of water.

2153b. Three Drawings of compound marine steam-engines, constructed and fitted on board H.M.S. "Constance" in 1863, by Messrs. Randolph, Elder, and Co., Glasgow. *John Elder and Co.*

They were the first compound engines fitted in any of H.M. ships, and have two 60 inch cylinders, four 78 inch cylinders, and a stroke of 3 feet 3 inches, and have surface condensers.

No. 1, plan, looking forward.

No. 2, cross sectional elevation, looking forward.

No. 3, cross sectional elevation, looking astern.

2153c. Model of the bridges used on board H.M.S. "Orontes" for carrying and launching ships' life-boats. *John White.*

This is a working model of Mr. J. White's plan, adopted by the Admiralty for H.M. ships of war and Indian relief troop ships, for carrying and launching life-boats from ships' upper deck.

2154. Model of Dawes and Holt's Marine Engine.
Henry S. Holt, C.E., Leeds.

This is of the vertical compound condensing type, without intermediate receiver between high and low pressure cylinders, and very short passages, reverse action of pistons, parallel motion, single crank and connecting rod, one vertical and one horizontal air pump, the former forming a counterbalance to connecting rod, and the latter is arranged to be used as a starting cylinder when required.

2155. Model, on a $\frac{1}{10}$ scale, of the horizontal condensing screw engines of H.M.'s ships "Nelson," built 1814, altered for the screw propeller 1860; "Conqueror," built 1833, altered for the screw propeller 1859; and "Tamar," built 1863. The engines are of 500 horse-power, nominal. Diameter of cylinders, 71 inches; stroke, 3 feet. Ravenhill, Easton, and Co., Engineers, Ratcliff, London. *South Kensington Museum.*

2156. Model (working), on a 3 inch to 1 foot scale, of the condensing vertical screw engines of steamship "A. Lopez," Cadiz and Havannah Spanish Mail Service.
South Kensington Museum.

The engines are constructed on the hammer or inverted cylinder principle, and have condensers, air and feed pumps, variable expansion gear, &c. The model is a complete working condensing engine of about 15 horse-power. It was made in 1866–7, and exhibited in motion at the Paris Universal Exhibition of 1867. W. Denny and Brothers, Engineers and Shipbuilders, Dumbarton.

Note.—The condensers of these engines are on Spencer's surface plan. They comprise a large central box, on the top edges of which rest the cylinders. The piston rods, two to each piston, work down by the sides of the condenser, and move in guides carried by the sides of the box. The pumps are worked off the cross heads, which are suitably prolonged for the purpose.

2157. Screw Engine. High-pressure non-condensing screw engine of 3 horse-power, for screw steam launches. Constructed on the hammer or inverted cylinder principle. Diameter of cylinder, 5 inches. Stroke, 6 inches. A. Verey and Co., Engineers, Dover. *South Kensington Museum.*

2158. Drawing, on a 1 inch to 1 foot scale, of the compound inverted cylinder screw engines of the steamships "Edinburgh Castle" and "Windsor Castle," built and engined in 1872 by the donors of the drawing. R. Napier and Sons, Engineers, Glasgow.
South Kensington Museum.

Note.—The engines are of 270 horse-power, nominal, having surface condensers, air and feed pumps, link motion for reversing, &c.

Diameter of high-pressure cylinder, 44 inches.

Diameter of low-pressure cylinder, 72 inches.

Stroke, 3 feet 6 inches.

The steamships belong to Messrs. Donald Currie and Co.'s Colonial Line of Mail Steamers, and run direct between London and the Cape of Good Hope.

2159. Model, on a scale of $1\frac{1}{2}$ inch to 1 foot, of the oscillating cylinder paddle-wheel condensing engines of the Holyhead and Kingstown Royal Irish Mail Steamer "Leinster." 750 horse-power, nominal. Diameter of cylinders, 98 inches; stroke, 6 feet 6 inches. *South Kensington Museum.*

To the engines are attached, on the same scale, the feathering float paddle-wheels of the ship, which are 32 feet in diameter. The floats are 12 feet long by 4 feet 10 inches deep. Ravenhill, Easton, & Co., Engineers, Ratcliff, London.

Note.—The length of the "Leinster" is 350 feet over all. Beam, 35 feet; depth of hold, 21 feet. Tons, 2,000. The ship has 8 boilers, 4 fore and 4 aft the engines, having 40 furnaces fired in line with the keel. The draught of the ship is 8 feet 6 inches on an even keel, and her speed about 21 statute miles per hour. She was built by Messrs. Samuda Brothers, Poplar, in 1860.

2159a. A Model of Direct-acting Screw Engines, date 1850, made for the Danish Government by Maudslay, Sons, and Field. *Maudslay, Sons, and Field, Engineers, Lambeth.*

2159b. A Model of Direct-acting Screw Engines, as fitted in 1851 by Maudslay, Sons, and Field in the mail steamers from London to Calcutta, and from London to the Cape of Good Hope. *Maudslay, Sons, and Field, Engineers, Lambeth.*

2159c. A Model of Horizontal, Double Piston Rod, Direct-acting Screw Engines, as fitted in H.M.S. "Agincourt," 1,350 horse-power nominal, and in H.M. ships "Prince Consort," "Caledonia" and "Ocean," each 1,000 horse-power nominal. *Maudslay, Sons, and Field, Engineers, Lambeth.*

2159d. Model of Beam Engines, similar to those of the "Great Western" steamship. This model was made by the late Henry Maudslay.

Maudslay, Sons, and Field, Engineers, Lambeth.

2159e. Model of Feathering Screw, by the late Joseph Maudsley. Date 1848.

Maudslay, Sons, and Field, Engineers, Lambeth.

2159f. Model of Paddle Wheel of "Great Western" steamship, designed by the late Joshua Field, F.R.S.

Maudslay, Sons, and Field, Engineers, Lambeth.

2159g. Drawing showing the four cylinder compound engines designed and fitted by Maudslay, Sons, and Field in the steamers of the "White Star" line, and in those of the "Compagnie Générale Transatlantique."

Maudslay, Sons, and Field, Engineers, Lambeth.

2159h. Drawing of the "London Engineer," 70 horse-power, a vessel fitted with a central paddle wheel, and air-tight paddle case, in the year 1818, intended to run to Margate. The scheme did not succeed, owing to the difficulty of keeping a sufficient supply of air in the paddle case to keep down the level of the water. *Maudslay, Sons, and Field, Engineers, Lambeth.*

2160. Model of the engines of the paddle-wheel steamer "Helen McGregor," of Liverpool.

Designed in 1843 by G. Forrester & Co., Engineers. G. Forrester & Co., Liverpool. *South Kensington Museum.*

Note.—This engine has two inverted steam cylinders driving one crank on paddle shaft, and a very long stroke. It occupies but little hull space. The engine is a condensing low-pressure engine, and is said to be still at work, 1873.

2161. Model of a paddle marine engine, designed by J. Scott Russell, F.R.S.; having three oscillating cylinders, all connected to one crank on the paddle shaft. One of the cylinders is vertical, the other two are inclined inwards at about 45°. J. Scott Russell, F.R.S. *South Kensington Museum.*

2162. Drawing, coloured, of a patented multi-flue marine boiler for high pressure; by Messrs. R. & W. Hawthorn, 1868. Scale, $\frac{1}{2}$ inch to 1 foot. R. & W. Hawthorn, Engineers, Newcastle-on-Tyne. *South Kensington Museum.*

Note.—The drawing shows a front view and cross section of the boiler. Longitudinal through sections and cross sections. A sectional plan.

2163. Model of a set of patent high-pressure marine tubular steam boilers; designed for the continuous use of fresh water. William Gray, Dawlish. *South Kensington Museum.*

Note.—These boilers possess the following arrangements:—They are fired from each end, the furnaces having special air-flues designed to assist in the combustion and the consumption of smoke. They are multi-tube boilers, having steam superheaters, and over all large tanks to contain fresh water, which supply the boilers with heated feed water. The working pressure is 100 lb. per square inch.

2164. Drawing. Sections of Gray's patent high-pressure marine steam boilers, showing arrangement of the tubes, steam superheater, water heater, and flues. Scale, $\frac{1}{2}$ inch to 1 foot. W. Gray, Dawlish. *South Kensington Museum.*

2165. Drawing, on a $\frac{3}{4}$-inch to 1-foot scale, of an improved marine tubular steam boiler; for high pressure. Designed and patented by Messrs. J. and F. Howard. Made by the Barrow Shipbuilding Co., Barrow-in-Furness. J. and F. Howard, Engineers, Bedford. *South Kensington Museum.*

Note.—The drawing shows a front view of the boiler, side elevation, longitudinal through section; and a section through tube plates showing method of coning joints, on a quarter full-size scale.

2166. Drawing of Messenger's patent high-pressure vertical water-tube boiler; for steam yachts and launches. Designed by Thomas Messenger about 1869. A. Verey and Co., Engineers, Dover. *South Kensington Museum.*

2167. Steam Donkey Engine and Pump, single-acting, for feeding steam boilers with water. Alexander Wilson and Co., Engineers, Vauxhall Works, Wandsworth Road, S.W.
South Kensington Museum.

Note.—Diameter of steam cylinder, $3\frac{1}{2}$ inches; stroke, 4 inches. Diameter of pump, $1\frac{7}{8}$ inches. Will pump 460 gallons per hour, and feed a 30 h.p. steam boiler.

2168. A Helm Indicator for the prevention of Collisions at Sea. *John James Nickoll.*

It is a lantern which is hoisted under the mast-head light of a steamer, and connected with the helm by rods or chains, and acts automatically with the rudder like a tell-tale, showing a green light when she is starboarding, and a red light when she is porting her helm, thereby showing the course a vessel is *about* to steer, and *before* she answers her helm or deviates from her course.

2168a. A pair of Ship's Side Lights with lenses.
John James Nickoll.

Guaranteed to show the light on all the points, the distance required by the regulations for preventing collisions at sea. The lenses are so constructed as to prevent the smallest amount of absorbing light colour, and the burner requires no chimney.

2168b. Wave-Indicator. An instrument intended for the direct tracing of the height of the waves, and for deducing their form. *Vice-Admiral Paris, Paris.*

2168c. Rolling-Indicator. An instrument indicating the rolling of ships, not only at its extreme amplitude, but during all its periods. *Vice-Admiral Paris, Paris.*

These two instruments are due to the late Lieutenant Armand Paris, son of the Admiral.

2169. Set of (eight) Models of the Block-making Machinery invented by Sir Isambard Brunel, for the use of Government, and set up in Portsmouth Dockyard by Messrs. Maudslay and Sons in 1804, where it has remained in use to the present time. *Royal Naval Museum, Greenwich.*

2170. Plan for Feathering a Screw Propeller, proposed by Messrs. Maudslay, Sons, and Field, 1848.
Royal Naval Museum, Greenwich.

2171. Hirsch's Screw Propeller.
Royal Naval Museum, Greenwich.

2172. Four-bladed or Two-bladed Screw Propeller.
Royal Naval Museum, Greenwich.

2173. Working Model of a pair of **Inverted Cylinders Marine Engine** for driving a screw propeller. Cylinders $2\frac{7}{8}$ inches bore, stroke 4 inches, link motion and reversing gear complete, shut-off valve, &c. Full sized partly shaded drawings of same. Made by exhibitor during his apprenticeship.
Robert Lathbury.

2174. Model in mahogany of a **Three-bladed Griffiths' Patent Screw Propeller.** Made by exhibitor during his apprenticeship. *Robert Lathbury.*

2175. Models (3) of **Varying-pitch Screw Propellers.** Woodcroft's Patent, 1838. *Bennet Woodcroft, F.R.S.*

2176. Varying-pitch Screw Propeller on shaft.
Bennet Woodcroft, F.R.S.

2177. Skeleton Model of part of a **Vessel** fitted with a **Screw Propeller.** (Cummeron's Patent, 1828.)
Bennet Woodcroft, F.R.S.

2178. Model of **Vessel** fitted with **Screw Propeller,** by Sir Francis Pettit Smith. *Bennet Woodcroft, F.R.S.*

The propeller consists of two whole turns of a screw thread round its shaft, and is placed in the dead wood or run of the vessel, but by a memorandum of alteration the patentee limits himself to a screw of one turn or two half turns.

2178a. A Photograph of the "Germanic" and "Britannic" mail steamers, belonging to the "White Star" line from Liverpool to New York. An abstract log of one of the voyages of the "Germanic" is attached to the frame. 760 horse-power nominal, four cylinder compound engines by Maudslay, Sons, and Field. Ships built by Harland and Wolff, of Belfast.
Maudslay, Sons, and Field, Engineers, Lambeth.

2178b. Model of a Yarmouth Herring Fishing Lugger getting her nets in. Exact model and position of men when at their work. *John Bracey.*

2178c. Model of a Yarmouth Trawling Smack. Without the trawl net. *John Bracey.*

2178d. Model of a Bow of a first rate ship-of-war, showing the disposition of the frames and hawse pieces. *Wm. Moody.*

2178e. Model of a Stern of a first rate ship-of-war, showing the disposition of the stern timbers and frames.
Wm. Moody.

2178f. Model of the Stern of a 50-gun frigate, showing the disposition of the stern timbers. *Wm. Moody.*

2178g. Model of the Stern of a 50-gun frigate, showing the disposition of the stern timbers. *Wm. Moody.*

2178h. Model of a Jury Rudder as fitted to the arctic schooner "Intrepid." *Wm. Moody.*

2178i. Model of a Bermudian Boat, "Pearl." *Wm. Moody.*

2178j. Model of the State Barge in which William III. landed at Greenwich, 1689. *Wm. Moody.*

2178k. Model showing the method of framing a screw aperture of a line of battle ship, to enable the screw to be raised or lowered at pleasure. *Wm. Moody.*

2178l. Model of a Midship Section, showing the method of framing a first rate wooden ship-of-war. *Wm. Moody.*

2178m. Model of the Bow of a first rate ship-of-war, "Prince of Wales." *Wm. Moody.*

Series of Iron Mail Paddle Steamers, designed and built by the late John Laird, M.P., from 1840 to 1860.

2178n. Model of H.M.S. "Dover," 1840. Length 113 ft., breadth 21 ft., depth 9 ft. $10\frac{1}{2}$ ins. 228 tons. 90 horse-power. *Laird Brothers.*

This was the first iron mail steamer, and was built for the Admiralty in 1840. She carried the mails between Dover and Calais for many years, and afterwards did good service on the coast of Africa.

2178o. Model of "Lord Warden," 1847. Length 160 ft., breadth 24 ft., depth 10 ft. 9 ins. 446 tons. 160 horse-power. *Laird Brothers.*

Built for the South-eastern Railway Company in 1847, and is still running as one of their despatch boats between Folkstone and Boulogne.

2178p. Model of "Cambria," 1848. Length 196 ft., breadth 27 ft., depth 14 ft. 6 ins. 716 tons. 370 horse-power. *Laird Brothers.*

Built for the Chester and Holyhead Railway Company for their despatch service between Holyhead and Dublin, was lengthened in 1860, and is still running as a cattle boat.

2178q. Models of the "Ulster," "Munster," and "Connaught," 1860. Length 334 ft., breadth 35 ft., depth 19 ft. 2,039 tons. 750 horse-power. *Laird Brothers.*

Built for the City of Dublin Steam Packet Company, for the mail service between Holyhead and Kingston, in 1860.

The "Connaught" attained a speed of over 18 knots, or 21 statute miles, per hour on her official trial at Stokes Bay.

These three vessels, together with the "Leinster," built by Messrs. Samuda, still perform this service.

SERIES OF IRON VESSELS, DESIGNED AND BUILT BY THE LATE JOHN LAIRD, M.P., AND THE PRESENT FIRM, AS SURVEYING SHIPS, MEN-OF-WAR, &C.

2178r. Model of H.E.I.C. "Euphrates" and "Tigris," 1834. Length 105 ft., breadth 19 ft., depth 7 ft. 6 ins. 179 tons. 50 horse-power. *Laird Brothers.*

Built for the Hon. East India Company for General Chesney's expedition for the exploration of the River Euphrates. These vessels were built by Mr. Laird at Birkenhead, 1834, then taken to pieces and shipped to the coast of Syria, and after having been carried across the desert by camels, they were put together and launched on the banks of the Euphrates by artisans sent from Birkenhead for the purpose.

Three similar vessels of very light draught, the "Nimrod," "Nitocris," and "Assyria," of 153 tons, each carrying two 9-pr. pivot guns, were built for the navigation of the Tigris and Euphrates a few years later.

2178s. Model of H.E.I.C. "Nemesis," 1839. Length 169 ft., breadth 29 ft., depth 10 ft. 3 ins. 660 tons. 120 horse-power. *Laird Brothers.*

Built for the Hon. East India Company for service on the coast of India, and armed with two 32-pr. pivot guns.

This vessel, as well as the "Phlegethon," a similar but rather smaller vessel, though only drawing 5 feet of water, made the passage out to India round the Cape, a drop rudder and sliding keel, as shown on model, being fitted for that purpose.

Under the command of Captain (now Admiral Sir William) Hall, R.N., the "Nemesis" did distinguished service in the China wars, her light draught enabling her to perform service which no wooden vessel in the fleet was able to accomplish.

At the same time the "Medusa" and "Ariadne," of 432 tons, and each carrying two 24-pr. pivot guns, were built for the same service.

2178t. Model of the "Guadaloupe," 1842. Length 187 ft., breadth 30 ft., depth 16 ft. 788 tons. 180 horse-power. *Laird Brothers.*

The success of the above steamers (the first iron vessels armed with heavy guns) induced the agents of the Mexican Government to order the steam frigate "Guadaloupe," of 800 tons and 180 horse-power, armed with two 68-pounder pivot guns, one at each end, and four 24-pounder broadside guns. The satisfactory reports made upon the construction and trials of this vessel by the late Mr. Large and other officers induced the English Government to entrust Mr. Laird with the designing and building of the iron paddle-wheel frigate "Birkenhead," 1,400 tons, one of the first iron war ships in the English navy; this ship was launched in 1845.

2178u. Models of the "Parana" and "Uruguay," 1873. Length 152 ft., breadth 25 ft., depth 12 ft. 6 ins. 455 tons. 80 horse-power. *Laird Brothers.*

Iron screw gunboats of modern type, built for the Government of the Argentine Confederation, armed with two 100-pr. Vavasseur pivot guns. Rigged as barques and fitted with Bevis' patent feathering screw propeller.

2178v. Models of the "Fu-Shêng" and "Chien-Shêng," 1875. Length 87 ft., breadth 26 ft., depth 8 ft. 8 ins. 256 tons. 40 horse-power. *Laird Brothers.*

Iron screw gunboats for coast and river defence, armed with one 18-ton Vavasseur gun, 450-pr., fitted with twin screws.

These vessels steamed out to China through the Suez Canal.

2178w. Models of the "El Plata" and "Los Andes," 1875. Length 180 ft., breadth 44 ft., depth 11 ft. 9 ins. 1,588 tons. 750 indicated horse-power. *Laird Brothers.*

Armour-plated twin screw turret vessels, built for the Government of the Argentine Confederation. Protected with armour 6 inches on the hull and 8 inches on the turret, and carry each two 12½-ton 300-pr. rifled guns.

They steam 9½ knots on a load draught of water of 9 ft. 6 ins., and steamed from the Mersey to Buenos Ayres in about 50 days, including all stoppages.

SERIES OF IRON PADDLE-WHEEL VESSELS FOR COMMERCIAL PURPOSES, DESIGNED AND BUILT BY THE LATE JOHN LAIRD, M.P., AND PRESENT FIRM.

2178x. Model of the "John Randolph," 1834. Length 110 ft., breadth 22 ft., depth 7 ft. 6 ins. 249 tons. 60 horse-power. *Laird Brothers.*

The first iron steamer ever seen on American waters, built at Birkenhead, taken to pieces, shipped at Liverpool, rivetted together on the Savannah river, where for many years after she did service as a tug boat.

2178y. Model of the "Garryowen," 1834. Length 130 ft., breadth 21 ft. 6 ins., depth 9 ft. 3 ins. 263 tons. 90 horse-power. *Laird Brothers.*

Paddle steamer built for the City of Dublin Steam Packet Company, for the navigation of the lower Shannon, and the largest iron vessel built at this time. After 30 years' service in Ireland the machinery was taken out of her and she was made into a sailing ship.

About the year 1841, at Mr. Laird's suggestion, this vessel was placed at the disposal of the Admiralty to enable them to institute a series of experiments on the variation of the compass in iron vessels, which were conducted by Capt. Johnson, R.N., and subsequently elaborated by the experiments carried out by Professor Airy on General Steam Navigation Company's steamer "Rainbow," built by Mr. Laird in 1837.

2178z. Model of the "Helen McGregor," 1843. Length 180 ft., breadth 26 ft., depth 15 ft. 573 tons. 220 horse-power. *Laird Brothers.*

Built for carrying passengers and cattle between Hull and Antwerp; one of the largest vessels of her class.

2178aa. Model of the "Countess of Ellesmere," 1852. Length 160 ft., breadth 20 ft., depth 7 ft. 6 ins. 315 tons. 80 horse-power. *Laird Brothers.*

Fast paddle passenger steamer, formerly running on the Mersey, afterwards sold as a yacht to the Grand Duke Constantine of Russia.

2178ab. Model of the "Earl Spencer," 1874. Length 253 ft. 6 ins., breadth 29 ft., depth 14 ft. 9 ins. 1,067 tons. 350 horse-power. *Laird Brothers.*

Showing present type of passenger and cattle steamers; built for the London and North-western Railway Company for service between Holyhead and Greenore. Speed, 15 knots.

SERIES OF IRON SCREW STEAMERS, DESIGNED AND BUILT BY THE LATE JOHN LAIRD, M.P., AND THE PRESENT FIRM, FROM 1838.

2178ac. Model of the "Robert F. Stockton," 1838. Length 63 ft. 5 ins., breadth 10 ft., depth 7 ft. 33 tons. 30 horse-power. *Laird Brothers.*

One of the first screw steamers ever built; fitted with Ericsson's screw propeller.

The propeller was unshipped for the voyage made under canvas from Liverpool to New York, where she was employed for many years as a tug boat.

2178ad. Model of the "Forerunner," 1852. Length 161 ft. 6 ins., breadth 22 ft., depth 11 ft. 4½ ins. 381 tons. 50 horse-power. *Laird Brothers.*

Built for MacGregor Laird, Esq., the founder of the African Royal Mail Steam Navigation Company, of which she was the pioneer vessel.

2178ae. Model of the "Nubia," 1854. Length 292 ft., breadth 39 ft., depth 27 ft. 9 ins. 2,173 tons. 450 horse-power. *Laird Brothers.*

Type of screw mail and passenger steamer of her date. Built for the Peninsular and Oriental Steam Navigation Company, and still carrying the mails in their service.

2178af. Model of the "Africa," 1871. Length 285 ft., breadth 34 ft., depth 23 ft. 3½ ins. 1,627 tons. 200 horse-power. *Laird Brothers.*

One of the modern steamers of the African Royal Mail Company, for same service as "Forerunner."

2178ag. Models of the "Corcovado," "Puna," and "Britannia," 1872. Length 375 ft., breadth 43 ft., depth 33 ft. 9 in. 3,434 tons. 600 horse-power. *Laird Brothers.*

Type of screw mail and passenger steamer of present date.

Built for the mail and passenger service of the Pacific Steam Navigation Company.

The "Corcovado" made her first voyage from Liverpool to Callao, 11,000 knots, in 33½ days, equal to a mean speed of 13·54 knots.

SUNDRY MODELS AND PLANS.

2178ah. Model of Bow of Vessel, showing bow rudder, with guard on. Patent taken out by the late Mr. John Laird in 1843. *Laird Brothers.*

Very generally adopted for all double-ended river steamers, and fitted in several paddle-wheel gun vessels.

2178ai. H. E. I. Co. "Napier," 1843. Length 160 ft., breadth 24 ft., depth 5 ft. 446 tons. 90 horse-power. *Laird Brothers.*

Built for the Hon. East India Company on a plan patented by Mr. Laird in 1843, with a spoon-shaped bow, and lifting dead wood and rudder.

This form of vessel combines speed, light draught of water, and good steering, with great carrying capacity, and was found to answer so well for the difficult navigation of the River Indus that a large number of river steamers were afterwards constructed by Mr. Laird for the Hon. East India Company on same system.

2178aj. Model prepared by the late William Laird, Esq., in 1836, to show application of the screw propeller to a frigate or troop ship of large size. *Laird Brothers.*

2178ak. Picture of the "Rainbow," 1837. Length 185 ft., breadth 25 ft., depth 11 ft. 9 ins. 581 tons. 180 horse-power. *Laird Brothers.*

Paddle steamer for passenger and cargo service, built for the General Steam Navigation Company of London, for service between London and Ramsgate. After being employed in London and Antwerp trade for some time, the "Rainbow," which was the fastest vessel of her day, ran for many years as a cargo steamer between Havre and London, and was in service till 1869.

2178al. Picture of H.M.S. "Soudan," "Albert," and "Wilberforce," 1840. Length 138 ft., breadth 27 ft., depth 8 ft. 8 ins. 459 tons. 70 horse-power. *Laird Brothers.*

Built for H.M. Government for the exploration of the River Niger.

2178am. Picture of the Ferry Steamer "Nun," 1840. Length 105 ft., breadth 20 ft., depth 8 ft. 9 ins. 187 tons. 60 horse-power. *Laird Brothers.*

The picture shows the "Nun" grounded on the stone pier at Birkenhead, her after end resting on the pier, and her bow on the bare rock below, the distance between the points of support being 81 ft.; the whole weight of the machinery, 65 tons, being in the middle of this unsupported space. She floated off the succeeding tide without having received the slightest damage.

This incident, which occurred in 1842, went far to confirm the growing confidence in the strength of iron ships.

2178an. Model of the "Marajo," 1874. Length 221 ft., breadth 32 ft., depth 10 ft. 3 ins. 1,099 tons. 200 horse-power. *Laird Brothers.*

Type of river steamer of modern construction, having large carrying capacity for passengers and cargo, on light draught of water, and great speed, and being fitted with compound oscillating engines.

2178ao. Half-block Model of S.S. "Viceroy." Built 1871. Length 320 ft., breadth 37 ft. 6 ins., depth, keel to upper beams, 20 ft. 3 ins., depth, keel to main beams, 32 ft. 3 ins. Tons B.M. 2,225. Tons nett register 1,851. *R. and H. Green.*

2178ap. Half-block Model of Ironclad Ram "Arapiles." Built for the Spanish Government, 1863. Length 279 ft. 4 ins., breadth 54 ft., depth 32 ft. 5 ins. Tons burthen 3,547. Screw engines, horse-power 800 nominal. 34 guns. *R. and H. Green.*

2178aq. Half-block Model of H.M. Ironclad Batteries "Glatton" and "Trusty." Built 1855. Length 172 ft. 6 ins., breadth 45 ft. 1 in., depth 14 ft. 9½ ins. Tons 1,546. Engines horse-power 150 nominal. *R. and H. Green.*

2178ar. Whole Model of East Indiaman "Falmouth." Built 1752. *R. and H. Green.*

2178as. Whole Model of Merchant Sailing Ship "Seringapatan." Built 1837. *R. and H. Green.*

2178at. Half-block Model of Paddle Tug "Rienzi." Built 1875. Length 114 ft. 6 ins., breadth 20 ft., depth 11 ft. Tons B.M. $218\frac{35}{94}$. Horse-power 70 nominal. *R. and H. Green.*

2178au. Half-block Model of Sailing Ship "Agamemnon." Built 1855. Length 244 ft., breadth 36 ft. 6 ins., depth 16 ft. 6 ins. Tons $1{,}536\frac{67}{94}$. *R. and H. Green.*

2178av. Half-block Model of Sailing Ship "Nile." Built 1850. Length 173 ft. 8 ins., breadth 36 ft. 6 ins., depth 16 ft. Tons $1{,}038\frac{29}{94}$. *R. and H. Green.*

2178aw. Half-block Model of Sailing Ship "Carnatic." Built 1833. Length 130 ft. 6 ins., breadth 32 ft. 6 ins., depth 14 ft. 7 ins. Tons 595. *R. and H. Green.*

2178ax. Half-block Model of Sailing Ship "Melbourne." Built 1874. Length 260 ft., breadth 40 ft., depth 24 ft. Tons register 1,965, tons O.M. 2,008. *R. and H. Green.*

2178ay. Half-block Model of Sailing Ship "Carlisle Castle." Length 220 ft., breadth 38 ft., depth 22 ft. 10 in. Tons register 1,458, tons O.M. 1,514. *R. and H. Green.*

2178az. Drawing, Profile of Captain Dicey's Channel Steamer "Castalia." *Thames Iron Works Co., Millwall.*

2178ba. Drawing, Main Deck Plan of Captain Dicey's Channel Steamer "Castalia."
Thames Iron Works Co., Millwall.

2178bb. Drawing, Section of Captain Dicey's Channel Steamer "Castalia." *Thames Iron Works Co., Millwall.*

2178bc. Original Whole Model of the Steam Boat "Comet." Built on the Clyde by J. Wood for Mr. Henry Bell, at Port Glasgow, 1811. Length 42 ft., breadth 11 ft., depth 5 ft. 6 ins. *John Reid and Co.*

In August 1812, the steam passage boat "Comet," being the first steam vessel ever built in Europe, began to run between Glasgow, Greenock, and Helensburgh, with passengers only. She was advertised to leave the Broomielaw on Tuesdays, Thursdays, and Saturdays, at an hour suitable to the tide, and to return from Greenock on Mondays, Wednesdays, and Fridays. The fares were 4*s.* for the best cabin, and 3*s.* for the second, and no gratuities to the vessel's servants were allowed. The boat was driven by a condensing steam-engine of 4 horse-power. She had at first two sets of paddle-wheels on each side of the vessel (shown in the model). Her greatest speed was five miles per hour.

2178bd. Whole Model of the Sailing Ship "Cairnsmore." Built 1854 by John Reid and Co., Port Glasgow, for Messrs. Nicholson and McGill, Liverpool. Length 223 ft., breadth 33 ft. 6 ins., depth 20 ft. 6 ins. Tons O.M. 1,211. This ship made her first passage from Clyde to Bombay in 65 days.
John Reid and Co.

2178be. Collection of Rope and Cordage for Ships' Use. Made by Thomas and William Smith.
T. and W. Smith, Newcastle.

2178bf. Drawings of the Sailing Ships "Falmouth," 1752; "Friendship," 1790; "Royal William," 1726. (Three drawings.) *R. and H. Green.*

2178bg. Half-block Model of SS. "Sultan." Built 1870. *R. and H. Green.*

2178bh. Half-block Model of Ship "Japanese."
W. Roydon.

2178bi. Two whole Models, illustrating framings in wood of old ships. *W. Roydon.*

2178bj. Model of the SS. "Nina," iron built.
Richardson, Duck, and Co.

2178bk. Model of the SS. "El Rahmanieh." Built for His Highness the Viceroy of Egypt. *Richardson, Duck, and Co.*

2178bl. Whole Model in Bone of a Three-decker Line of Battle Ship, made by French prisoners in England during the Peninsular War, 1812. *Vaughan Pendred.*

2178bm. Model showing Interior of a Wooden Merchant Ship.
Lloyd's Register of British and Foreign Shipping, Cornhill.

2178bn. Model showing the Framing of the Fore Body of a Wooden Merchant Ship.
Lloyd's Register of British and Foreign Shipping, Cornhill.

2178bo. Model showing the Framing of the after Body of a Wooden Merchant Ship.
Lloyd's Register of British and Foreign Shipping, Cornhill.

2178bp. Model of a Diagonally Framed Ship.
Lloyd's Register of British and Foreign Shipping, Cornhill.

2178bq. Model of a Ship Sheathed with Diagonal Doubling Plank.
Lloyd's Register of British and Foreign Shipping, Cornhill.

2178br. Model of an Old Ship showing Framing-deck, Beams, &c., also lower masts and bowsprit in place.
Lloyd's Register of British and Foreign Shipping, Cornhill.

2178bs. Model of Mr. John White's System of constructing Composite Iron and Wood Vessels.
Lloyd's Register of British and Foreign Shipping, Cornhill.

2178bt. Sectional Model of an Iron Vessel.
Lloyd's Register of British and Foreign Shipping, Cornhill.

2178bu. Drawing of a Composite Vessel, showing the iron framework, and the mode of fastening the wood bottom.
Lloyd's Register of British and Foreign Shipping, Cornhill.

2178bv. 20 Drawings, illustrating Lloyd's Rules and Regulations for Commerical Shipbuilding on Mr. J. White's Composite or Iron and Wood system.
Lloyd's Register of British and Foreign Shipping, Cornhill.

2178bw. Model of H.M. Gun Boat "Staunch." Built by C. Mitchell and Co., Newcastle-on-Tyne.

C. Mitchell and Co.

The "Staunch" was built in 1868, as the type of a new class, which has since been largely introduced with the British and other services. Length of vessel 75 feet, beam 25, depth 8 feet, armament one 12½ ton gun. Engines are of 40 horse-power nominal with twin screws.

2178bx. Model of Armour Clad Frigate "Prince Pojarski." Built for the Imperial Russian Government by C. Mitchell and Co., Newcastle-on-Tyne. *C. Mitchell and Co.*

The dimensions of vessel are, length 280 feet, beam 49 feet, depth 31 feet, armament eight 300-pr. contained in central battery. Machinery, 600 horse-power nominal, and speed of vessel about 13 knots per hour.

2178by. Model of Paddle Steamer "Baron Osy." Built by C. Mitchell and Co., Newcastle-on-Tyne, in 1875, for the Société Anversoise de Bateaux à Vapeur, to perform an improved passenger service between London and Antwerp. Dimensions are, length 240 feet, beam 30 feet, engines 250 horse-power, and speed 13 knots per hour. *C. Mitchell and Co.*

2178bz. Glass Case containing Models of Ships built by the Company.

The Thames Iron Works and Shipbuilding Company.

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H.M.S. "Serapis" (half model), English Government, troop ship.
"Victoria" (half model), Spanish Government, ironclad.
"Konig Wilhelm" (half model), Imperial German Government, iron clad.
"Mesondige" (half model), Sultan of Turkey, ironclad.
"Pervenetz" (half model), Czar of Russia, ironclad.
H.M.S. "Waterwitch" (half model), English Government, ironclad.
"Vasco da Gama (half model), Portuguese Government, ironclad.
"Absalon" (half model), Danish Government, ironclad.
"Aoni Illah" (whole model), Sultan of Turkey, ironclad.
"King George" ,, Hellenic Government, ironclad.
"Castalia" ,, iron steamer for channel service.
Glass case section of H.M.S. "Warrior," English Government.

2178ca. 13 Mounted Drawings, midship sections of various vessels built at the Thames Iron Works, and showing the advance in the thickness of armour plating from 1855 to 1876.

The Thames Iron Works and Shipbuilding Company.

2178cb. Working Drawing, by John Wood, port Glasgow, of the "Comet," built by him in 1811 for Henry Bell.

R. Napier.

The "Comet" was the first vessel propelled by steam that regularly traded in Europe.

This drawing was presented by John Wood to R. Napier.

The *engine* of this vessel was presented by R. Napier and Sons to the South Kensington Museum.

2178cc. Model of the Paddle Steam Yacht "Menai," supplied by R. Napier in 1830 to Thomas Assheton Smith.

R. Napier.

The hull, 132 feet long, 20 ft. 6 ins. broad, 12 ft. 8 ins. depth of hold, and $146\frac{1}{94}$ tons register, was built by John Wood, port Glasgow, from Mr. Smith's design, the vessel's bottom having a hollow or channel on each side of centre keel.

The engines were made and fitted by R. Napier. Cylinders $42\frac{3}{4}$ ins. diam. × 4 feet stroke, 120 nominal horse-power.

2178cd. Drawings of the Engines of the Paddle Steamer "British Queen." Constructed in 1838 for the British and American Steam Navigation Company, London, by R. Napier, Glasgow. *R. Napier*

The hull, 275 ft. long, 39 ft. 8 ins. broad, 27 ft. 6 ins. deep (moulded), was built by Messrs. Curling and Young, London.

Cylinders, $77\frac{3}{4}$ ins. diameter × 7 feet stroke, 420 nominal horse-power.

These engines (the largest marine engines made at the time they were constructed) were fitted with Hall's surface condenser.

2178ce. Model of the Paddle Steamer "Faid Zafar." Length 225 ft. 6 ins., breadth 20 ft., depth 8 ft. 7 ins. 360 tons gross. *David and William Henderson & Co.*

Built and engined by the late firm of Tod & McGregor in 1864, for His Highness Ismail Pacha, Viceroy of Egypt, being completely composed of steel for light draught of water, schooner rigged.

Engines oscillating, cylinders 44 ins. diameter, stroke 3 ft., horse-power 120 nominal, speed 20 miles per hour.

2178cf. Model of the Paddle Steamer "Mukhbir Suroor." Length 220 ft., breadth 20 ft., depth 9 ft.

David and William Henderson & Co.

Built of iron and engined by the late firm of Tod & McGregor in 1864, for His Highness Ismail Pacha, Viceroy of Egypt, as tender to the "Faid Zafar," schooner rigged.

Engines oscillating, cylinders 40 ins. diameter, length of stroke 3 ft., horse-power 100 nominal.

2178cg. Model of the Screw Steamer "City of Manchester." Length 262 ft., breadth 36 ft., depth 25 ft. 2,096 tons gross. *David and William Henderson & Co.*

Built and engined by the late firm of Tod & McGregor in 1851, for the Inman Company, to trade between Liverpool and New York; barque-rigged, with jigger, about the first vessel ever fitted with *iron masts.*

Engines beam-geared, cylinders 71 ins. diameter, length of stroke 5 feet, horse-power 370 nominal.

2178ch. Model of the Screw Steamer "City of Richmond." Length 440 ft., breadth 43 ft. 6 ins., depth 34 ft. 4,606 tons gross. *David and William Henderson & Co.*

Built and engined by the late firm of Tod & McGregor in 1873, for the Inman Line to trade between Liverpool and New York. Ship rigged.

Engines, direct acting compound inverted, cylinders 76 ins. and 120 ins. diameters, length of stroke 5 ft.; propeller 22 ft. diameter; horse-power 670 nominal; speed at trial trip, 17 knots per hour; 10 boilers, 30 furnaces.

2178ci. Model of the Screw Steamer "Princess Royal." Dimensions, length 200 ft., breadth 28 ft., depth 15 ft. 527 tons gross. *David and William Henderson and Co.*

Built by the late firm of Tod & McGregor in 1861, for the Glasgow and Liverpool trade, schooner rigged.

Engines, direct acting inverted, compounded in 1873 by having 2 high pressure cylinders 24 inch diameter placed on top of the 45 inch cylinders—length of stroke 2 ft. 6 ins., horse-power 170 nominal, propeller 12 feet diameter, speed 12 knots per hour.

2178cj. Model of the Screw Steamer "Lady Nyessa." Dimensions, length 150 ft., breadth 14 ft., depth 6 ft. *David and William Henderson and Co.*

Built by the late firm of Tod & McGregor in 1861, for the late Dr. Livingstone, for exploration in Central Africa. To facilitate transportation of the vessel from the Zambesi to Lake Nyessa, she was constructed in 12 segments in her length, each segment being in two pieces which were bolted together through angle iron frames. Dr. Livingstone on his return home from Africa, on his first exploration, sailed in her from the Zambesi to Calcutta. The "Lady Nyessa" was fitted with two propellers, one abaft the other on the same shaft.

Engines high pressure, cylinders 14 ft. diameter, length of stroke 12 inches, horse-power 25 nominal.

2178ck. Model of the Screw Steamer "Bengal." Dimensions, length 297 ft., breadth 39 ft., depth 27 ft. 6 ins. 2,235 B.M. tons. *David and William Henderson and Co.*

Built by the late firm of Tod & McGregor in 1852, for the Peninsular and Oriental Steam Navigation Co., lately trading in the China Seas.

Engines beam geared, cylinders 80 inches diameter, stroke 5 feet, horse-power 470 nominal.

2178cl. Model of the Paddle Steamer "Trafalgar." Dimensions, length 190 ft., breadth 28 ft. 6 ins., depth 16 ft. 4 ins. 689 tons gross. *David and William Henderson and Co.*

Built and engined by the late firm of Tod & McGregor in 1847, for Messrs. Wm. Watson & Co., Dublin, for their Liverpool and Dublin trade, schooner rigged.

Engines oscillating, cylinders 69 inches diameter, length of stroke 5 feet 6 inches, horse-power 360 nominal.

2178cm. Model of the Paddle Steamer "Princess Royal." *David and William Henderson and Co.*

Built and engined by the late firm of Tod & McGregor in 1841, for the Glasgow and Liverpool trade; wrecked in 1856, and a new paddle steam vessel built in 1857 to replace her.

Engines, steeple, cylinders 72 inches diameter, length of stroke 6 feet 6 inches, horse-power 400 nominal.

2178cn. Model of the Paddle Steamer "Countess of Galloway." Length 165 ft., breadth 24 ft., depth 14 ft. 3 ins.
David and William Henderson and Co.

Built and engined by the late firm of Tod & McGregor. Two vessels were built from this model and of the same name, one in 1835 and one in 1843, fitted up as passenger and cattle-boats plying between Liverpool and Wigtown; the latter vessel is still on her station, and is considered one of the best cattle-boats afloat. Owned by the Galloway Steam Navigation Company, rigged 3-masted schooner.

Engines vertical, direct-acting, cylinders 54 inches diameter, length of stroke 5 feet, horse-power 220 nominal, paddle wheel 22 feet diameter.

2178co. Model of the Twin Paddle Steamer "Alliance." Dimensions 140 ft. by 9 ft., breadth of each hull, depth, 8 ft., distance between hulls, 12 ft., total breadth, 30 ft.
David and William Henderson and Co.

Propelled by one paddle wheel, 18 feet diameter, placed between hulls, 27 ft. 6 ins. abaft centre of vessel. The paddle wheel was afterwards taken out of the centre and the two halves rivetted together; since that alteration she made several successful passages as a blockade runner during the late American war. The "Alliance" was built by the late firm of Tod & McGregor in 1856, for Clyde river traffic.

Cylinders, 34 inches diameter length of stroke, 3 feet horse-power, 70 nominal.

2178cp. Model of the Merchant Vessel "Brotherly Love." Built in the year 1764, and still reigning. The mark on the side is for damage in a collision with a steamer some years ago. *James Young.*

2178cq. Model of the Merchant Vessel "Antelope." Built in the year 1757. *James Young.*

2178cr. Model of a Shields Pilot's Coble.
James Young.

2178cs. Model of the Mast of the Man-of-war "Nelson," in seven pieces, without the pieces which form the top.
James Young.

DIMENSIONS, WEIGHT, AND EXPENSE OF THE "NELSON'S" MAIN MAST.

	£	s.	d.
No. 1. Expense of seven trees	860	16	6
2. Hoops, bolts, and nails	61	11	6
3. Smith work	16	4	0
4. Mast makers	55	0	7¼
	993	12	7¾

	ft.	ins.
Length - - -	127	$2\frac{1}{4}$
Greatest diameter - -	0	41
Smallest diameter - -	0	$30\frac{3}{8}$

	tons	cwt.	qr.	lbs.
Weight - - -	26	0	3	24

2178ct. Photograph of the "Comet" and "Tona" Steamers, 1811, 1874. *John Hamilton.*

From a painting by Wm. Clark-Greenock, to illustrate and keep on record the appearance of the first British steamer, and also to make a comparison between the past and present types of Clyde river steamers.

2178cu. Half Model of an Iron Screw Steamer, showing about 23 ft. of midship body, with a Price's patent self-turning hatchway fitted. *William Denton.*

The adoption of this new style of hatch opening in the vessels already fitted with Price's patent has effected very large saving in the cost of loading, as trimming is entirely dispensed with. The pamphlet containing testimonials explains the opinions of the owners, who have adopted the invention. With a lithograph showing profile of vessel fitted with Price's hatchways, also detailed sketches of manner of fitting half-booms, hatch sides, &c.

2178cv. Half Model of Iron Merchant Vessel "Donnybrook." Length 260 ft., breadth 40 ft., depth 24 ft. Built 1876 by Messrs. Austin and Hunter. Tonnage 1,700 tons, water draught 21 ft. *Austin and Hunter.*

2178cw. Half Model of Carr's Steamer "Decapolis," built of iron. Length 260 ft., breadth 32 ft., depth $23\frac{1}{2}$ ft., tonnage 1,000 tons, draught of water 20. Built 1876 by Messrs. Austin and Hunter. *Austin and Hunter.*

2178cx. Model of Merchant Ship "Cherubim." Length 156 ft., keel 136 ft., breadth 28 ft., depth 18 ft. *Thomas Wrightson.*

2178cy. Model of Passenger Steamer "North Star." Length 316 ft., depth 23 ft., breadth 36 ft., tonnage 2,500 tons. *Thomas Wrightson.*

2178cz. Model of the "Crest of the Wave," a noted China clipper, built by the late William Pile, Sunderland, and owned by John Hay, Esq. and others, Sunderland. Built in 1853 of wood. Length 180 feet, breadth 32 feet, depth 20 feet. Classed 13 years A1. in Lloyd's registry ; 776 tons register. *R. H. Hay.*

2178da. Model of the wood clipper vessel "Aurora Borealis," built by the late William Pile, Sunderland, and owned by John Hay, Esq., Sunderland, in 1850. *R. H. Hay.*

2178db. Model of the wood clipper vessel "Herald of Light," built by the late William Pile, Sunderland, in 1850, and owned by Henry Ellis, Esq., London. *R. H. Hay.*

2178dc. Model of the stern of an iron sailing ship fitted with patent rudders, to be used when the main rudder is damaged or carried away; also to be used in conjunction with the main rudder when required. *George Stavers.*

2178dd. Model of the stern of a steamer fitted with patent rudders, to be used when the main rudder is damaged or carried away. *George Stavers.*

They can also be used in conjunction with the main rudder to increase the steering power to prevent collisions. The wheel is fitted with a double set of tiller ropes; the fore one connects the main rudder and the after one the patent rudders.

2178de. Model of the "Dover Castle" (wood). Built for Richard Green, Esq., Blackwall, in 1858. Length 185 ft., breadth 22 ft., depth 34 ft., tonnage 1,002 nett. *John Haswell.*

This vessel was draughted and model made by Master George Haswell, son of the builder, when 15 years old.

2178df. Model of the "Min" and "Sumida," sister ships. Built for the Japanese Government by R. Thompson, junior. Length 268 ft., breadth 32 ft. 1 in., depth 21 ft. 4 ins. *Robert Thompson, junior.*

2178dg. Model of the "Lady Louisa." Built for Wilson and Co., London, by R. Thompson, junior. Length 152 ft., breadth 28 ft. 3 ins., depth 17 ft. 9 ins. *Robert Thompson, junior.*

2178dh. Model of the "Life Brigade." Built for E. Shotton and Co., North Shields, by R. Thompson, junior. Length 249 ft. 5 ins., breadth 32 ft. 4 ins., depth 17 ft. 15 ins. *Robert Thompson, junior.*

2178di. Model of the "Graham" (wood). Buillt for Edmund Graham, Newcastle, by Robert Thompson and Sons, designed by Robert Thompson, junior. Length B.P. 132 ft., breadth 30 ft. 4 ins., depth of hold 20 ft. 10 ins. *Robert Thompson, junior.*

2178dj. Model of the "Opal." Composite corvette, by William Doxford and Sons. Length 220 ft., breadth 40 ft., depth 21 feet. *Wm. Doxford and Sons.*

2178dk. Model of the Screw Steamer "Adalia." Built for E. T. Gourley, Esq., M.P., by William Doxford and Sons. Length 231 ft. 6 ins., breadth 32 ft., depth 24 ft. 8 ins. *Wm. Doxford and Sons.*

2178dl. Model of Composite Gunboat "Cygnet." By William Doxford and Sons. Length 125 ft., breadth 23 ft. 6 ins., depth 12 ft., horse-power 360. *Wm. Doxford and Sons.*

2178dm. Model of Passenger Screw Steamer "Gloria" built for Olano Larrinaga & Co., Liverpool, by William Doxford and Sons. Length 322 ft., breadth 38 ft. 3 ins., depth 30–55. *Wm. Doxford and Sons.*

2178dp. Set of Original Block Models from which the following vessels were built in wood:—

"Victory," barque, built in 1847, length 113 ft., breadth 22 ft. 8 ins., depth 13 ft. 6 ins. Classed 7 years A1., tonnage 239 tons.

"St. George," Snow collier, built in 1847, length 78 ft., breadth 23 ft., depth 12 ft. 3 ins. Classed 8 years A1., tonnage 153 tons.

"Providence," schooner, fruit trade, built in 1850, length 69 ft., breadth 17 ft., depth 10 ft. Classed 7 years A1., tonnage 83 tons.

"Bury St. Edmunds," full-rigged ship, built in 1853, length 155 ft., breadth 31 ft., depth 21 ft. Classed 13 years A1., tonnage 701 tons. *Peter Forster.*

2178dq. Model of the Composite Clipper Sailing Ship "Torrens" (Elder line of packets to Adelaide). Built by James Laing, Sunderland, in 1875. Length 222 ft., breadth 38 ft., depth 21 ft. 6 ins. 1,334 tons, gross. *James Laing.*

2178dr. Model of the Peninsular and Oriental Steam Navigation Company's Vessels "Khiva" and "Kashgar." Built by James Laing, Sunderland, in 1874. Length 370 ft., breadth 36 ft. 8 ins., depth 27 ft. 4 ins. 2,600 tons gross. *James Laing.*

2178ds. Model of the Hamburg South American Steam Ship Company's S.S. "Buenos Aires." Built by James Laing, Sunderland. Length 340 ft., breadth 36 ft. 4 ins., depth 25 ft. 6 ins. 2,400 tons gross. *James Laing.*

2178dt. Model of Sailing Ship "Vimiera." Built in 1850 by James Laing, Sunderland, for the late Duncan Dunbar. Length 165 ft., breadth 33 ft., depth 23 ft. 1,037 tons. *James Laing.*

The side of this model can be opened to show the construction of the ship.

2178du. Model of the Peninsular and Oriental Steam Navigation Company's S.S. "Poonah," as altered and refitted by James Laing, Sunderland. Length 414 ft., breadth 41 ft. 6 ins., depth 27 ft. 4 ins. 3,118 tons gross. *James Laing.*

2178dv. Model of Screw Steamer "Lestris." Built by Joseph L. Thompson and Sons, Sunderland. Length 227 ft., breadth 30 ft., depth of hold 17 ft. *Joseph L. Thompson and Sons.*

2178dw. Model of Sailing Ship "Baroda." Built by Marland and Wolfe, Belfast. Length 225 ft., breadth 36 ft., depth 23 ft. 9 in. *P. Phorson.*

2178dx. Model of a Vessel built about 1844 by James Leithead Pallion, Sunderland. *P. Phorson.*

2178dy. Model of the wooden Ship "Chowringhee." Built by the late Wm. Pile, of Sunderland, for the late John Hay, Esq., in 1857. Length 156 ft. 3 ins., breadth 31 ft. 6 ins., depth 21 ft. 6 ins. *Sunderland Corporation.*

2178dz. Plans and Elevations of Steamships "Marquess de Nuney" and "Wear." Built by the late Mr. Wm. Pile, Sunderland. *Mr. Skinner, Sunderland.*

2178ea. Model of Screw Collier "David Burn." Built in 1873 by Messrs. Wm. Doxford and Sons, Sunderland. *Alfred Simey and Co., Sunderland.*

This vessel was sunk off the Tyne by collision on her first trial trip. The visitors (chiefly ladies) were saved by the captain of the vessel which struck her, keeping her going at full speed, and filling the hole made by the collision

2178eb. Two Models of parts of a vessel, with the day and night helm indicating signal hoisted for preventing collisions at sea. *John James Nickoll.*

On moving the helm either to port or starboard, the indicator will move, showing which way the helm is, and consequently which course a vessel is about to steer.

2178ec. Transparency showing the effects of the helm indicating signals for preventing collisions at sea. *John James Nickoll.*

2178ed. A pair of Coloured Lenses for railway and other signals, calculated to show the signals upwards of two miles. *John James Nickoll.*

The green signals can be seen at a much shorter distance than the red; this green lens will show a distance of *three miles.*

2178ee. Model of an Anchor invented by Sir Edward Belcher when a midshipman, 1815. *Admiral Sir Edward Belcher, K.C.B.*

2178ef. Model of a method of mending an Anchor when the shank has been broken, 1830. The method is by means of 3 pieces of pig-iron. *Admiral Sir Edward Belcher, K.C.B.*

2178eg. Model in Silver. Patent "Stockless" anchor, small craft anchor. *Wasteneys Smith, C.E.*

2178eh. Model in Brass. Patent "Stockless" anchor. *Wasteneys Smith, C.E.*

These anchors are said to possess—

1. Great holding power, with less weight, besides being diminished in the weight of the stock.
2. Extraordinary strength, proved at Lloyd's test.
3. It is always canted, no matter how it falls, and requires no stock to keep it canted.
4. Being always canted when on the ground, and by the assistance of the horns or toggles, it takes hold as soon as any strain is put upon the cable.
5. Spare, and wider, and different shaped arms for various grounds may be carried on board.
6. It will not foul or get fouled, and when holding there is nothing above ground, nor is there any stock to cause accidents.
7. It trips with great ease, because there is no stock to lift, and the crown end has so large a surface that good purchase is obtained for weighing.
8. It is easily fished, and can be stowed in-board on deck, thus clear of the bow, and avoiding risk of damage in case of collision of any description.
9. A ship may speedily be brought up by it, and ride with very short cable; the steadying power being at the crown end, it is of no object if the shank is raised off the ground, which stocked anchors will not allow.
10. In shallow water no damage can occur to a ship's bottom, as no part of the anchor projects above ground.
11. It is at least one-third shorter than ordinary anchors, therefore soon clear of the water, and more convenient to manage.
12. It can readily be disconnected, thus convenient to stow and easy to transport in case of need, its heaviest part being less than one-third its total weight.
13. It is made without welding, thus of great soundness.
14. It is worked with only one davit (being hoisted and let go by the fish shackle), therefore considering the saving of first cost and future maintenance of one davit and blocks, &c., it is by far the cheapest anchor to use, besides greatest safety and simplicity in working.
15. It is not dangerous when at "wash," for in the event of a collision, the arms would simply be flattened to the ship's side instead of being driven in.
16. Should the anchor be difficult or dangerous to weigh, from having got fast in rock or wreckage, a runner with messenger attached may be slipped down the cable to the crown end, and by this means the anchor can be drawn out freely, as there are no barbs or palms to retard it.
17. Being of such greater strength and holding power, and requiring less cable than other anchors, shorter and stronger cables may be carried, thus increasing the safety of the ship without additional weight or cost.

2179. Model of **J. Ericsson's Screw Propeller Engines,** applied to the American and Swedish Monitors, patented in America in 1858.

Lent from the Patent Office Museum by the Commissioners of Patents.

2180. Models of Screw Propellers.
Council of King's College, London.

2180a. Model of a Propeller for Ships.
S. F. Pichler, London.

2180b. Model of Bevis's Patent Feathering Screw Propeller. *Laird Brothers.*

Mr. R. R. Bevis, managing engineer to the firm of Messrs. Laird Brothers, of Birkenhead, in 1868 patented an arrangement for altering the pitch or feathering the blades of a screw propeller in a fore and aft direction, which claims to be a great advantage for screw steamers, making them faster and more handy when under sail alone, and when under steam and sail allowing of adjusting the pitch to obtain the best result. A screw propeller of the ordinary kind, whether fixed or revolving, is a heavy drag against speed and handiness for sailing, and "lifting" it is a laborious operation, and requires a large hole or well through the ship's counter to admit of so doing.

The arrangement of this new screw propeller is free from many of the objections which have been made to feathering screws previously tried. The gear for feathering the blades is well protected, the levers and other gear that move the blades being enclosed within the boss of the screw propeller, and attached to a rod passing through the centre of the shaft, which is worked in the screw shaft tunnel. This system is admirably adapted for ships of war or sailing ships with auxiliary power or yachts, where it is as important to have a good result under sail alone as under steam. The operation of altering the pitch, or of feathering the blades to any angle, is done in a few minutes, without in any way putting the engines into a position that they may not be used in an emergency.

2180c. First Helmet made for Diving Purposes, date A.D. 1829. *Siebe and Gorman.*

2180d. Patent Helmet for Diving, fitted with segmental neck ring and safety locking arrangement, inflating valve for bringing diver to the surface. Fitted with speaking apparatus to enable the diver to communicate with his attendant. Used on board H.M. Ships of the Royal Navy. *Siebe and Gorman.*

VIII.—LIGHTHOUSES AND FOG SIGNALS.

2181. Model of a **Lighthouse** built upon the **Bishop Rock,** 7 miles from land, forming part of the outermost reef S.W. of the Scilly Islands. *Trinity House, London.*

The tower is of Cornish granite (Carnsew), and is surmounted by a lantern of gun-metal, containing lenticular apparatus to exhibit a fixed light of the first order, whose focal plane is 110 feet above high-water spring tides. The structure measures from base to vane 147 feet. It was built from designs by the late James Walker, M.I.C.E., under the superintendence of Nicholas Douglass, for the Corporation of Trinity House, London, at a cost of 36,500*l.*, and occupied six years in construction; it was completed in 1853. A sectional drawing shows the method of bracing by vertical and radiating wrought-iron ties, lately adopted for strengthening the structure.

2182. Model of a **Lighthouse** now building upon the **Little Basses Rock,** part of a reef about 7 miles S.S.E. of the coast of Ceylon. *Trinity House, London.*

The tower is of Scotch granite (Dalbeattie), each stone of which was dressed, fitted, and marked in this country, freighted to Galle, and thence carried to the rock and fixed in its place. The light is intended to be of the first order, dioptric, on the group-flashing principle, showing two flashes in quick succession every minute, at an elevation of 110 feet above high-water spring tides.

The rock is awash at low water, and is exposed to heavy seas during both the N.E. and S.W. monsoons, and while the latter prevails is inaccessible for work. The drawings show the methods of landing stone in a seaway by steam-power.

This lighthouse, as well as its fellow on the Great Basses just completed, is building from designs by James N. Douglass, M.I.C.E., under the superintendence of William Douglass, M.I.C.E., for the Corporation of Trinity House, London, acting on behalf of the Home and Colonial authorities.

Its cost is estimated at 73,000*l.*, and completion is anticipated within five years from date of commencement.

2182a. Lantern and Apparatus intended for the Little Basses Lighthouse, Ceylon. *Trinity House, London.*

The lantern is of the cylindrical type adopted by the Trinity House, its form gives maximum strength, and secures greater optical accuracy than the earlier methods of flat glazing. The gun-metal framing is inclined about 30° from the perpendicular, and is helically curved throughout, thus reducing to a minimum the obstruction offered to the light sent forth from the lenses.

The optical apparatus, constructed upon the group-flashing principle, designed by J. Hopkinson, B.A., D.Sc., at the glass works of Messrs. Chance Brothers, is the first dioptric instrument of its kind adopted by the British lighthouse authorities. It is 12-sided, and makes a completed revolution in six minutes, so that the panels being arranged in pairs, a double-flash meets the eye of the observer once a minute.

The lantern and apparatus prepared for this structure are exhibited in working order in the grounds outside the Museum.

2183. Drawing of a **Light Vessel** with deck plans showing internal arrangements and disposition of Syren **Fog Signal** machinery. *Trinity House, London.*

The hull is designed after that of the vessel now at South Sand Head (Goodwin), built last year, of about 212 tons, and fitted with a syren fog-signal, giving one blast every two minutes, by means of compressed air, at a pressure of 30 lbs. to the square inch, the apparatus being driven by a caloric engine, which also works the windlass.

The illuminating apparatus represents that in use at the Royal Sovereign Shoal, off the coast of Sussex; it is catoptric, and is upon the "group-flashing" principle, giving three flashes in quick succession every minute. The crew space is for seven men, including the officer in charge. The hollow iron mast affords access to the lantern, and allows of the lamps being trimmed in all weathers without danger of extinction.

2184. Two **Syrens,** each a portion of the present **First Class Fog Signal,** and a diagram showing the method by which they are put in action. *Trinity House, London.*

The disc syren, with the trumpet by which its sound is directed, is shown in the diagram. It is composed of a fixed disc, forming one end of the chamber into which steam or compressed air is forced, and a movable disc rotating rapidly by separate mechanism outside it. Both are perforated by 12 radial slits exactly corresponding each to each, and the rotation of the moving disc, close to and upon a common axis with its fixed associate, permits the compressed air or steam to escape when the slits coincide, and shuts it off when they do not. The vibrations thus produced being repeated in the instrument described, at the rate of more than 400 per second, emit a sound of very great intensity, which is directed by the trumpet towards any desired point.

The cylindrical syren is a later form of the instrument, in which the chamber for compressed air surrounds a fixed cylinder having 24 slits, within which another cylinder coincidently perforated rotates, and the vibrations pass through the open end of the inner cylinder to the trumpet.

Syrens sounded by steam have for some time been used for fog-signalling on the coasts of America, and have lately been adopted, with the substitution of compressed air for steam, in Great Britain as a result of experiments made by the Trinity House with the assistance of Professor Tyndall during the winter of 1873.

2185. Fog Signal Apparatus. Designed by Dr. G. Amadi, of Trieste.

The Imperial and Royal Maritime Government at Trieste.

By this apparatus deep tones, like those of an organ, are produced by metallic tongues, driven by steam, and sent through a trumpet in a given direction. These, from experiments, have extended as far as 16 nautical, or nearly four German miles.

In working this apparatus, of which already three are in use, at Trieste, Salvore, and Grado, the sounds are made self-producing at certain intervals by means of a steam-engine.

2185a. Holmes' Shipwreck Distress Signal Flare and Life Buoy Rescue Lights.

These have the remarkable property of bursting into flame when placed in contact with water, and when once ignited are absolutely inextinguishable by either wind or water. They emit a most powerful white light, as brilliant as the magnesium light, and continue to burn over 30 minutes. The shipwreck distress signal flare is visible on a dark night with a clear atmosphere at a sufficient elevation for over ten nautical miles, and burns with greater brilliancy the more seas sweep over it.

The light is a chemical light, and produced by the action of the water upon phosphuret of calcium, giving off phosphuret of hydrogen, which, combining with the oxygen in the atmosphere, spontaneously ignites. These distress signals are free from danger, are not affected by heat, friction, or percussion, and contain no explosive compound whatever.

2185b. Holmes' Mechanical Compound Reed Fog Horn.

These mechanical fog alarms are constructed upon the most approved acoustical principles, and emit a most powerful sound. The "aurora" fog horn can be heard over three nautical miles, and the note produced is the 8 foot C of the musical scale. The tone is produced by the vibrations of two metal tongues, placed together in absolute contact, and closing the same reed,

by which means (the split tongue) a powerful vibration is set up with a minimum pressure of air. The air bellows consist of two metal cylinders, one working inside the other; and the compressed air upon the return of the cylinder is driven through the reed into an inner trumpet-shaped tube contained within and a part of the external cylinder.

2186. Parabolic Reflector of 21-inch aperture.

Trinity House, London.

Composed of copper coated with pure silver in the proportion of 3 ozs. (troy) pure silver to 1 lb. (avoirdupois) copper. Its focal distance is 3 inches.

Improvements in the construction of light vessels' lanterns have permitted the introduction of this large sized reflector into that service, in which a 12-inch aperture had hitherto been the limit of size.

2187. Centrifugal Governor. A mechanical arrangement used for controlling the movements of the clockwork machinery, by means of which a light is made to revolve on board a light ship. *Trinity House, London.*

Before this contrivance was designed by Mr. Slight of the Trinity Workshops, there was always a tendency to irregularity in the periods of duration of the light and the interval of darkness, but the centrifugal governor ensures the working of the revolving machinery with very great accuracy.

2188. An **Improved Six-Concentric-wick Lamp,** for burning vegetable or mineral oil. *Trinity House, London.*

The burner hitherto in use for dioptric apparatus of the first order has carried four concentric wicks, and in burning has been maintained at full power in all weathers. In the improved six-wick burner, designed by J. N. Douglass, M.I.C.E., only the three outer wicks are to be used in ordinary weather, and in thick weather the three inner wicks (at other times cut off by a concentric reflector) are also brought into action. The full light-producing power of the six-wick lamp is equal to 722 standard sperm candles, attained by a consumption of 1 gallon of oil in 1 hour 50 minutes; its half-power equals 342 candles, with 1 gallon consumed in 2 hours 45 minutes. By a simple arrangement regulating the level of oil in the burner, and the position of the air-deflectors, the lamp can be made to burn any description of oil at pleasure.

2189. A **Panel** of **Cata-Dioptric Apparatus, One** of a set of **Polyzonal Lenses** manufactured in 1836 by Messrs. Cookson and Sons, of Newcastle, for the Trinity House of London, and by them fixed in the Start Point Lighthouse, Devonshire.

Trinity House, London.

The first lenticular apparatus used in an English lighthouse, with a central lamp upon Fresnel's principle.

2190. Plano-Convex Lens, used at Portland Lighthouse in the year 1789. *Trinity House, London.*

It is 22 inches in diameter, and was placed in front of an argand burner and reflector. It is believed to be one of the lenses first used in combination with an oil lamp and reflector for lighthouse illumination.

2191. Facet Reflector. Specimen of a reflector and lamp used first at Liverpool about the year 1763, and afterwards at Lowestoft and other lighthouses. *Trinity House, London.*

It is made of wood with facets of silvered glass, is nearly paraboloidal in form, and is the earliest kind of reflector known to have been used in aid of an oil lamp in lighthouse service.

2192. Lamp and **Reflector,** as used in English floating lights about the year 1809. The curve of the reflector is spherical.
Trinity House, London.

2193. Parabolic Reflector of **Plated Copper,** used in some of the **Northern Lighthouses.** When the apparatus is to be cleaned, the lamp is lowered out of the reflector on a sliding carriage, as arranged by the late Mr. Robert Stevenson in 1814. The object of the sliding carriage is to insure the return of the burner to the proper focus.
W. and T. Stevenson, Northern Lighthouse Office.

2194. Parabolic Reflector, formed by small facets of mirror-glass, imbedded in plaster of Paris, used in the earliest of the northern lighthouses till superseded by more perfect apparatus in the beginning of the present century.
W. and T. Stevenson, Northern Lighthouse Office.

2195. Model of a **First-class fixed Dioptric Light;** scale, one-fifth of full size.
W. and T. Stevenson, Northern Lighthouse Office.

This apparatus consists of a central lenticular band, and an upper and lower set of reflecting prisms. The cylindrical belt with diagonal joints and the upper and lower reflecting prisms were substituted by Mr. Alan Stevenson, in 1836, for the segmental belt, and upper and lower silvered mirrors of Fresnel's first-class apparatus.

2196. Model of a **First-class Fresnel Revolving Apparatus,** as made for Skerryvore Lighthouse in 1843; scale, one-fifth of full size.
W. and T. Stevenson, Northern Lighthouse Office.

The light is received and collected into eight horizontal beams by the principal lenses—the light which would escape above is collected into eight inclined beams by small lenses, and reflected to the horizon by inclined mirrors. The lower part of the light is sent equally to all parts of the horizon by prismatic rings of glass, which act as mirrors. The rings at Skerryvore are the first that were made of the largest or first order size, and were undertaken by M. Soleil, on the proposal of Mr. Alan Stevenson.

2197. Model of a **First-class Holophotal Revolving Apparatus;** scale, one-fifth of full size.
W. and T. Stevenson, Northern Lighthouse Office.

The central part of this apparatus consists of eight of Fresnel's lenses. The light which passes above and below these lenses is collected into eight horizontal beams by reflecting prisms. These reflecting prisms were substituted for the inclined lenses and mirrors of Fresnel's first-class revolving apparatus by Mr. Thomas Stevenson, and were first used by him at Singapore, in 1849, on a small scale, and adopted on a large scale at North Ronaldshay, in Orkney, in 1851.

2198. Dioptric Holophote, designed by Mr. T. Stevenson for lighthouse illumination.

W. and T. Stevenson, Northern Lighthouse Office.

This apparatus collects all the light of the lamp into one beam of parallel rays solely by means of glass. The apparatus constituting the front half of the instrument bends the light that falls upon it into a beam of parallel rays, while the prisms which constitute the back half are so formed as to prevent any light from passing through, and to cause every ray to return back to the flame, and to be finally transmitted through the front half, so as to increase the intensity of the emergent beam. A large red ball is fixed on a wire, so as to be in focus, to illustrate the action of the instrument. To an observer, the front half of the apparatus will appear full of red light, but in the back half no red is to be seen, though the wire which carries the ball, not being in focus, is distinctly visible.

2199. Fixed Azimuthal Condensing Light. Designed for the leading lights of the River Tay, by Messrs. Stevenson, civil engineers, Edinburgh.

W. and T. Stevenson, Northern Lighthouse Office.

It is remarkable from its employing every kind of dioptric apparatus. The whole of the light coming from the flame is spread equally over a horizontal arc of 45° by means of the following instruments; viz., Fresnel's fixed-light apparatus and annular lens, and Mr. T. Stevenson's condensing prisms, holophote, right-angled conoidal prisms, and dioptric spherical mirror, with Mr. J. T. Chance's setting.

2200. Model of an **Apparent Light.**

W. and T. Stevenson, Northern Lighthouse Office.

A beam of light, projected on the apparatus in the lantern on the beacon from a lighthouse on the shore, is reflected or refracted in such a manner as to indicate the position of the beacon at night. It was first used at Stornoway, in Scotland, in 1852.

2201. Model of the **Lamlash Apparatus,** showing the new twin prisms lately described by Mr. Thomas Stevenson in "Nature," which are now for the first time being constructed, and the new back prisms first introduced at Lochindaal Lighthouse, in Islay. *W. and T. Stevenson, Northern Lighthouse Office.*

2202. Lighthouse Apparatus.

1. Lens with échelons. 1st essay.	Fresnel,	inventor,	1819.
2. Polygonal lens, of the first order.	Do.	do.	1820.
3. Annular lens, of the first order.	Do.	do.	1821.
4. Apparatus for fixed lights.	Do.	do.	1824.
5. Apparatus with catadioptric rings.	Do.	do.	1825.

6. Lens with catadioptric rings, constructed in . 1825.
7. Model of apparatus with catadioptric rings. Fresnel, 1825.
8. Burner with 4 wicks, constructed after experiments made by Arago and Fresnel in . . . 1820.
9. Burner with 2 wicks, with external covering, by Henry Lepaute . . . . . . 1845.
10. Burner with 4 wicks, storied, for mineral oils.
11. Large annular lens of Barbier and Tenestre . 1876.
12. Lenticular pannel for flashing lights of Henry Lepaute 1876.
13. Apparatus for revolving electric lights, of Sanker, Lemonnier & Co. . . . . . 1876.

Lighthouse Service of France, Paris.

2202a. Echeloned Lenses.

Lighthouse Service of France, Paris.

No. 1. First essay of echeloned lens, polygonal form. Invented by A. Fresnel, and constructed under his direction in 1819.

No. 2. First echeloned lens, polygonal form, for flashing lights of the first class. Invented by A. Fresnel, and constructed in 1820.

No. 3. First echeloned lens, annular form, for flashing lights of the first class. Invented by A. Fresnel, and proceeding from the lenticular apparatus fixed on the tower of Cordouan in 1821.

When Fresnel conceived the idea of substituting in lighthouses large glass lenses for metallic reflectors, he thought of composing these lenses of several pieces, and of calculating the curves of these different pieces so as to rectify their spherical divergence. He demonstrated his plan before the Lighthouse Committee in August 1819, three months only after his appointment on the Committee, and on the 19th of October following he was granted the sum of 500 fr. for constructing a trial lens. He consulted the optician Soleil, who seconded him with much good will, but who could only put at his disposal the limited appliances then in use. Glass was at this time worked still by hand, and shaped only into plane or spherical forms. Fresnel admitted that the lens should be flat on one side; that the different gradients, instead of forming circular rings, should be defined by polygons and divided into a certain number of pieces, each of which should receive on its echeloned side a spherical surface properly calculated. Another difficulty arose from the glass factories being unable to supply in sufficient size pieces of crown glass free from bubbles and striæ; but Fresnel discovered the way of re-smelting glass without altering its transparency.

He first constructed a trial lens of 35 centimetres diameter (the one exhibited under No. 1). It was given by Soleil to the Academy of Sciences, and deposited at the "Conservatoire des Arts et Métiers." It is composed of 21 pieces, glued together, and fixed upon a pane serving as a support.

Emboldened by this first success, Fresnel proposed to the Lighthouse Committee, at their sitting of 31st December 1820, to order the construction of a lenticular revolving light apparatus for the Cordouan lighthouse. The principal part of this apparatus was to include eight square lenses of 76 centimetres, forming together an octagonal prism inscribed within a cylinder of 2^m diameter. This proposal was adopted, and Mr. Soleil undertook the construction of these eight polygonal echeloned lenses. (One of them is exhibited under No. 2.) It is to be seen that it was composed of 100 pieces of glass, glued together, and that the flat pane, which in the trial lens serves as a support, has been done away with. One of these new lenses was first

tried in public on 13th April 1821. It was placed on the top of the Observatory buildings, together with two large reflectors, one by Lenoir, the other by Bordier-Marcet. The Lighthouse Committee, of which Mr. Becquey, director-general of the "Ponts et Chaussées," was chairman, went to the summit of Montmartre to judge of the effect. The result confirmed the inventor's previsions, and every one allowed the superiority of the lens over the reflectors. Meanwhile, Fresnel had already thought of improving these first essays. He had invented a machine for constructing circular rings, and M. Soleil was instructed to make eight large lenses constructed on annular principles. He soon finished some of them, and in September 1821 the Lighthouse Committee determined to try their effect at long distances. Fresnel had fitted up on the top of the "Arc de l'Etoile" a revolving apparatus upon which were fixed two of these annular lenses, four polygonal lenses previously constructed, and four semi-polygonal lenses. At the focus, a four-wicked lamp was burning. The committee then went to Chateney, a village situated N.N.E. of Paris, $24\frac{1}{2}$ kilometres distance from the "Arc de l'Etoile." The experiment took place during the night of 7/8 September 1821, and the results were adjudged as very satisfactory. The eight annular lenses that had just been constructed form part of the first flashing-light apparatus of the 1st class that Fresnel himself fixed on the watch-tower of Cordouan, and which has lighted the entrance to the Gironde for more than 30 years. (The lens exhibited under No. 3 comes from this apparatus.)

If an idea is to be formed of the progress made in the science of lenticular lighthouses from its origin to later times, the three lenses before mentioned should be compared with the lenses of modern construction exhibited under Nos. 11, 12, and 13.

Fixed Light Apparatus.

No. 4. First fixed light apparatus of $0{\cdot}50^{m}$ diameter, invented by A. Fresnel, and constructed in 1824.

Fresnel, after his appointment to the Lighthouse Committee of 1819, first gave his attention to flashing lights ; meanwhile, he had thought about obtaining fixed lights, and in the first design of the lenticular lighthouse that he submitted to the committee on 31st October 1820, he indicated, as a solution, the use of cylindrical lenses ; but the Lighthouse Committee had thrown aside the fixed light system as possessing less reverberating power that revolving lights, and as being liable to be mistaken for the incidental lights of the coast. The committee altered this decision later, and Fresnel then invented the system of fixed light apparatus (0.50^{m} diameter), exhibited under No. 3. In this apparatus the lenticular drum, which should be cylindrical, so as to give an uniform subdivision of light, shows a polygonal form of 16 fasces, because no lathe was then known for making cylindrical pieces. The upper part is made up of two lenticular zones in the shape of a 16-panel cupola, every element of which is coupled with a plane mirror. The lenses unite in parallel fasces the rays emitted by the light, and the mirrors reflect them in the direction of the horizon.

A similar system, but having one lenticular zone only, is fitted at the lower part. The lamp has two wicks, and stands upon a plate raised or lowered by a jack between three leaders. With the polygonal form that had to be adopted, there were 16 directly receiving more light than the intermediate parts, but Fresnel, while constructing the instrument, discovered the means of greatly lessening this inequality, by alternating the shining directions of the lenticular cylinders with those of the two other parts. This first trial of a fixed light apparatus was demonstrated by Fresnel before the Academy of Sciences of Paris, at their sittings of 3rd May 1824. It was then inaugurated on the 1st February 1825 in the port of Dunkirk.

Catadioptric Rings.

No. 5. First apparatus containing catadioptric rings, as well for fixed light as for flashing lights, invented by A. Fresnel, for lighting the St. Martin Canal, and constructed in 1825.

No. 6. Annular lens, composed of dioptric and catadioptric elements, similar to those of apparatus No. 5, and constructed at the same date.

No. 7. Models in wood of an apparatus similar to No. 5, but on a larger scale. Study of A. Fresnel in 1825.

The last invention of A. Fresnel, that of the catadioptric rings, was promoted by a request for information addressed to him by the Prefect of the Seine in 1825. It was a question of applying to the lighting the quays of the St. Martin's Canal more powerful lamps than those used commonly in the city of Paris. This problem, to which Fresnel's attention was called, was the same as that of the port-lights apparatus, of which he had postponed the study because the sidereal reflectors of Bordier-Marcet were sufficient to supply the wants of the service.

The principal part of these small apparatus, that is, the lenticular cylinder, offered no theoretical difficulty. It was to proceed out of an echeloned section turning around the vertical axis; the only thing was to construct it in circular shape, because the polygonal shape would have been impossible for rings of 20 to 25 centimetres diameter. The question was not so easily solved as regards the accessory parts intended to utilise the luminous rays passing outside the cylinder, because the reflectors used in the other classes must now be reduced to too small dimensions. It was then that Fresnel thought of the phenomenon known in optics under the name of "total reflection," and imagined to substitute for the common reflectors glass rings, within which the luminous rays should be reflected without appreciable loss.

Fresnel's first conception for these circular rings was to direct the fasces through which the luminous rays pass perpendicularly to these rays, so as not to alter their direction; the reflecting surface would then have preserved the shape of the mirrors to be replaced, but hence resulted inconvenience, and a too great weight of glass. Fresnel found out that an inclined direction upon the rays could be given to these in and out going fasces, and thus these inclinations be combined, as well as the shape of the reflecting surface, so as to force the rays to emerge horizontally. The transverse section of the rings then became triangular, instead of showing four sides, and the dimensions lessened.

The apparatus exhibited is that to which Fresnel first applied this invention. Its diameter is reduced to $0\cdot20^{m}$; the cylinder is generated by an echeloned section composed of three elements and fills up a half circumference. The rays passing above this cylinder are gathered by four total reflection rings, and this is effected by turning around the vertical point of the focus the section of the catadioptric triangles just spoken of. Thus is obtained a fixed light apparatus, lighting up half the horizon. The lamps of the St. Martin's Canal having to be erected at 70 metres distance, it became necessary to give them a greater lateral than frontal intenseness. Fresnel succeeded in this by placing on each side a half annular dioptric lens, generated by the rotation of the section of the cylinder around an horizontal axis, parallel with the longitudinal direction of the quay, but he had moreover the happy idea of making the section of catadioptric triangles to revolve around this axis so as to form an annular lens, collecting around the focus an angle of great amplitude, and comprising at the same time dioptric and catadioptric rings.

The manufacture of these different circular rings offered serious difficulty, and Fresnel was obliged to set up a factory.

A first apparatus was completed in 1826, and submitted to the Lighthouse Committee towards the end of December. Four of these new lamps were

finished at the beginning of 1827, but they could not be tried until after the inventor's death.

This study shows how Fresnel came to invent not only the section of catadioptric rings, and the use of these rings in fixed light apparatus, but also their applying to annular lenses for flashing lights or for fixed lights. By uniting the pieces of dioptric elements and of catadioptric rings manufactured in Fresnel's time for the apparatus of the St. Martin's Canal, the annular lens exhibited under No. 6 was formed, and it may be considered as the type of all the annular lenses used in the lighthouses of different order.

The model in wood, No. 7, represents an apparatus similar to the preceding, but having a diameter of $0{\cdot}25^{m}$ instead of $0{\cdot}20^{m}$. It is a study of Fresnel's which he did not carry out.

Lamp Burners.

No. 8. One of the first burners, with four concentric wicks, constructed after experiments made by Arago and Fresnel in 1819–20.

No. 9. Burner, with two wicks and outer wrapper for directing the draught, constructed by Henry Lepaute in 1845.

No. 10. Burner, with five wicks, of graduated shape, for mineral oil, with the last improvements adopted in the lighthouses of France, 1876.

When Fresnel undertook the improvement of lighthouses, he had to solve not only the problem of construction of the lenses, but also that of lamps with several wicks. The chemist Guyton-Morvau had already studied the question. In a paper read by him at the Institute in 1797, he stated that he had constructed, 10 years before, a lamp on the argand principle, with three concentric circular wicks, each having an inner and an outer draught. He acquired great intenseness, but the solderings of the burner were destroyed by the heat. About 1800, the watchmaker Carcel invented the lamp that bears his name, and in which the oil at the bottom is forced up by a pump towards the burner above which it overflows. This invention was to lead towards solving the problem of lamps with many wicks. Consequently, when Arago and Fresnel began, in 1819, their experiments with lamps, they forced up the burner oil in superabundance so as to refresh it, and thus avoid the inconvenience met with by Guyton-Morvau. The first trial took place in September 1819 with two-wicked and three-wicked burners, constructed after Fresnel's designs. After several hesitations, respecting chiefly the width to be adopted for the draught between the wicks, they succeeded in constructing a four-wicked burner that gave good results. It was tried 12th May 1820, in presence of the Lighthouse Committee. The burner exhibited under No. 8 is one of those that were constructed according to this first type.

The two-wick burner, No. 9, was constructed by Henry Lepaute in 1845, for the lighthouse of Schevening in Holland. It has an outer cylinder for dividing the draught generated between the glass and the burner, and throwing back a part of it upon the light. It is the first application of this cylinder which exists in all modern burners.

The five-wick burner, No. 10, is a model of those now constructed for using mineral oil in the French lighthouses. It contains an appendage through which the oil must pass before reaching the upper part of the burner. This said piece, of which the arrangements were invented by M. Dénéchaux, acting engineer in ordinary at the lighthouse depôt, is intended to secure a continuous level, and comprises three tubes, juxtaposed, and open on the upper part at the proper height; the central tube springs from the small reservoir which forms the basis of the burner, and in which the oil is forced by the machinery of the lamp; this oil, having no other exit, rises in the tube, and, arriving at the top, flows into the second tube, which

carries it into the annular spaces containing the wicks; these it fills while keeping the same level as in the lateral appendage. As the quantity of oil forced up by the lamp is greater than the consumption, the excess comes down into the large reservoir of the lamp by flowing into the third tube over a fall rather higher than that cleared by the oil in reaching the burner. A horizontal disk of 30 millimetres diameter rises, at the height of 21 millimetres, above the central draught tube, and an outer cylinder divides in two the draught created between the burner and the glass. It is upon this outer cylinder that the glass-holder stands. In this burner the empty spaces between the wicks, intended for air passages, are 5½ millimetres wide, while the spaces that contain the wicks are only 4½ mill. In the burners constructed up to the present time, both widths are of 5 mill.; this new arrangement seems to give better results. The burner has, besides, on its upper part, a graduated shape, so that each wick is placed about 2 millimetres below the one which precedes it towards the centre. This arrangement, as yet adopted only for the Pilier lighthouse, exhibited under No. 12, has been found necessary since the burners, in each order of lighthouses, have had one burner added to them, and therefore are wider. Its object is to lower the edge of the burner, in reference to the centre of the light, so as to reduce as much as possible the portion of light obscured by this edge in the lower part of the lenses. (*See* description of apparatus, No. 12.)

Modern Apparatus.

No. 11. Great annular lens, of the first order, $1{\cdot}10^{m}$ in diameter, Messrs. Barbier and Fenestre, constructors, 1867. This lens was constructed by Messrs. Barbier and Fenestre as a specimen of high class workmanship. Each ring is one single piece; the joints which divide the rings are inclined according to the direction of the ray refracted. The lens is mounted on a pedestal, and revolves around any horizontal axis.

No. 12. Lenticular panel, dioptric and catadioptric, for flashing lights of the second class, planned by the head engineer, Allard, and constructed by Mr. Henry Lepaute, 1876.

This panel forms part of an apparatus intended for the Pilier lighthouse, situated at the mouth of the Loire, and of which the tower has just been rebuilt. The character given to it in 1829 has been preserved; it is a fixed light varied by flashes every four minutes To produce this character a fixed light apparatus has been adopted, of which two sectors of ⅛th horizon, opposed to one another, are replaced by perfect annular lenses; it revolves at the rate of one turn in eight minutes. In order that the two kinds of lenses may be adjusted upon the edges, and have a common pinion-jack, the focal distance, which is $0{\cdot}700^{m}$ for the fixed lenses, has been reduced to $0{\cdot}647^{m}$ for the annular lenses. The focal lamp has five concentric wicks, instead of four, as usual in lamps of the second class, because the light, being coloured red in certain directions, it was thought necessary to increase its intenseness.

This panel shows several novel arrangements, some of which are now applied for the first time.

1st. In the central or dioptric parts of the section, the joints that divide the elements, and therefore the lower sides of these elements, instead of being horizontal, are inclined according to the direction of the ray refracted. This system has several advantages: it does away with a triangular part of glass which is useless, and thus lessens the weight of the apparatus; it reduces in a large proportion the loss of light caused by horizontal joints; it makes less harsh, and consequently less fragile, the outer angles of the elements, and, besides, it diminishes their projection, thus enabling the dioptric lens to acquire a greater height.

2nd. The central lens (or dioptric) comprehends a vertical angle of 76 degrees, whereas, in the old sections, this angle was of about 60 degrees only; its elevation is thus increased from 0·85^{m} to 1·10^{m}. This advantage is thus obtained, that the luminous rays meet the last dioptric element at the same angle as the first catadioptric ring, and suffer no more loss of reflection upon the one than upon the other.

3rd. The section commonly used in apparatus of the second class had been calculated for a three-wick lamp burner of 0·074^{m} diameter. With a five-wick burner of 1·110^{m} diameter, the inferior elements of the dioptric lens and the lower catadioptric rings, constructed after this old section, emit rays that are no longer in the proper direction, because the portion of light which the base of the burner leaves visible becomes perceptibly nearer to the lens than in the case of a three-wick burner. To lessen this defect, a graduated shape was given to the burner, by placing each wick 0·002^{m} below the one preceding it on the side of the centre. This arrangement reduces neither the regularity nor the intenseness of the light, and the part of that light, visible from each of the lower lenticular elements, becomes somewhat increased. Moreover, these lower elements have been calculated by determining for each of them a particular focus taken on the brightest line of the apparent part of the light, instead of on the axis itself of the lamp. Similar arrangements might be advantageously adopted in many cases.

4th. The central lens and the lower rings are included in the same frame, the upper rings are set in a second frame, separated from the first by a metal cross-beam. In the annular lenses, this cross-beam takes the shape of the arc of a circle having, like the rings, its centre on the optical axis; the result is that the rings can remain intact, instead of having to be cut, as was the case until now.

5th. The lamp, placed at the focus of the lens exhibited, shows special arrangements, due to M. Dénéchaux.

Thus, the skin pockets or valvulæ, and the leathern valves, which are sometimes the cause of disorder, are replaced by ordinary pistons and metal valves. This system has produced good results in experiments made at the depôt, but it has not yet received practical sanction.

The lamp with five wicks for burning mineral oil has an intenseness of 36 carcel burners, the fixed light apparatus produces an intenseness of 640 burners, and the annular lenses produce an effulgence of more than 5,000 burners.

No. 13. Apparatus for electric revolving light, constructed by Messrs. Sautter, Limonnier, & Co., 1876.

This instrument is intended to produce, by electric light, a light revolving at intervals of 30 seconds. It includes a fixed light apparatus 0·50^{m} diameter, lighting the three-fourths of the horizon, around which revolves, in eight minutes, a tambour of 0·62^{m} diameter, and composed of 16 vertical, lenticular elements.

In the section of the fixed light apparatus the central dioptric part fills vertically an angle of 76 degrees, which is greater than in the old sections. This arrangement is adopted in order that the luminous ray may meet the last dioptric element at the same angle as the first catadioptric ring, and should suffer no more loss by reflection upon the one than upon the other. The apparatus having to be fixed on an elevated point, the section of the several parts, except that of the two lowest catadioptric rings, has been calculated so as to throw the focal line of the emergent rays, 30 minutes below the horizontal line; in the calculation of the two lowest rings, this angle is increased by three degrees for the last but one, and by five degrees for the last, so that the lighthouse may remain visible at a short distance, that is, by a navigator placed below the divergent cone emitted by the rest of the apparatus.

The sixteen vertical lenses are contiguous, and are each composed of a single element, about 0·12 wide, the curve of which has been calculated so as to give with the electric light an horizontal divergence of three degrees seven minutes. The duration of a flash is, accordingly, of about five seconds, and the interval between the end of a flash and the beginning of the following one is 25 seconds.

The maximum intenseness of the flash rises to about 60,000 burners, assuming at the focus an electric light of 200-burner power.

The light is produced in this apparatus, as in the lighthouses, with electric light, established on the coasts of France, by means of a Serrin regulator and an electrical machine of the Compagnie l'Alliance.

Experiments have been made with the Serrin regulator at the lighthouse depôt since the year 1860. A model on a large scale has been constructed especially for the lighthouse service, and has always given good results. The regulator exhibited is a counterpart of this model.

The electro-magnetic machine has been, as is well known, designed by MM. Nollet and Joseph Van Walderen, in accordance with the same principle as the scientific apparatus of Pixii and Clarke. It produces alternate currents, and, as it was in the first instance destined for the decomposition of water or for electro metallurgy, it was provided with a commutator for bringing the currents into one constant direction. When the question was raised of applying it to the production of light, M. Van Malderen, who had then become the mechanical engineer to the Compagnie l'Alliance, conceived the happy idea of suppressing the commutator, which is difficult to maintain, and has the effect of more or less weakening the current. The luminous intensity was found to be appreciably augmented, and the fact was soon acknowledged that alternate currents are, *cæteris paribus*, more favourable regulators than those in a constant direction. The machines of the Compagnie l'Alliance had originally six discs; these were reduced to four when the improvements introduced into the coils and the magnets permitted of a greater intensity being obtained with these smaller machines than with the former. In the case of lighthouses, where there cannot be too great intensity, the number of six discs has been preserved.

The central depôt in Paris has retained, since 1860, the first specimen constructed by M. Van Malderen of this machine, with the currents not brought into one constant direction. It has six discs, and carries 56 magnets; it is 1·63 metre high, and 1·43 metre in diameter; it gives less light than the present machines, but it works very well still, and serves for the experiments that are made at the dépôt.

This first machine of the Compagnie l'Alliance may be regarded as the starting point of all the attempts which have since been made of economically transforming power into electricity, and consequently into light. On that account it is no more than right, although the machine is not included in the Exhibition, to make mention of it in the catalogue.

2203. The Original Model of the Eddystone Lighthouse.

The Eddystone Rocks, so named from the great variety of sets of tides and currents which surround them, are situated about 14 miles S.S.W. of the port of Plymouth, the sea being fully 30 fathoms in depth. A lighthouse was constructed on these rocks by Winstanley in 1696, and destroyed by a storm in 1703. A second was built by Rudyerd in 1709, and was totally consumed by fire in 1755. The present lighthouse was commenced in 1756,

and completed in 1759, by Smeaton, F.R.S., civil engineer. This original model, made by Smeaton, was sent by royal command for the inspection of His Majesty George III. and the Royal Family, and has since then remained in the possession of Mr. Smeaton's family.

Mrs. Croft Brooke.

2203a. Model of the Lighthouse on La Corbière Rock, Jersey. *Sir John Coode.*

The first lighthouse constructed in concrete; tower erected in 1874. Sir John Coode, engineer. Modelled by Mr. Joseph Thomas. Scale, $\frac{1}{128}$ of natural size.

2203b. Parabolic Reflector, rendered holophotal, according to Mr. Thomas Stevenson's design, by being fitted with a lens and reflecting prisms, and a portion of a spherical mirror, so as to parallelise all the light of the lamp. Introduced in 1849.

The Commissioners of Northern Lighthouses.

When the apparatus is to be cleaned the lamp is lowered out of the reflector on a sliding carriage, as arranged by the late Mr. Robert Stevenson, in 1814. The object of the sliding carriage is to insure the return of the burner to the proper focus.

2204. Model of First-class Fixed Dioptric Light. This apparatus consists of a central lenticular band, and an upper and lower set of reflecting prisms. The cylindrical belt, with diagonal joints, and the upper and lower reflecting prisms, were substituted by Mr. Alan Stevenson, in 1836, for the segmental belt and upper and lower silvered mirrors of Fresnel's first-class apparatus.
(One-fifth of full size.)

The Commissioners of Northern Lighthouses.

2205. Model of Fourth Order Dioptric Condensing Apparatus for Lamlash Lighthouse, showing the twin prisms, 1875. (One-half of full size.)

The Commissioners of Northern Lighthouses.

2206. Model of Mr. Thomas Stevenson's Marine Dynamometer, for ascertaining the force of waves during storms. The greatest force recorded in the German Ocean was $3\frac{1}{2}$ tons per square foot. *Messrs. D. and T. Stevenson.*

2207. Drawing of Storm Curve, showing the genesis of waves illustrative of Mr. Thomas Stevenson's formula $h=1\cdot5\sqrt{D}$, where h=height of wave in feet, and D=length of fetch in miles.

Messrs. D. and T. Stevenson.

2208. Drawing illustrative of formula for the reductive power of harbours. *Messrs. D. and T. Stevenson.*

2209. Historical Series of published engravings, showing the improvements in lighthouse illumination between 1787 and 1876, by the Engineers of the Northern Lighthouse Board.

Messrs. D. and T. Stevenson.

2210. Example of **French Lighthouses.**

Lighthouse Service of France.

2210a. Polygonal and Annular Lenses. Apparatus for fixed light and for annular reflection; Arago and Fresnel's four-wick burner, two with burner of Henry Lepaute, &c.

Department of Lighthouses, France.

VIII.—MISCELLANEOUS.

2210b. Model of Tumbler Lock and Key.

Council of King's College, London.

2210c. Model of Ancient Egyptian Lock and Key.

Council of King's College, London.

2210d. Model of Mangle Motion.

Council of King's College, London.

2211. Steam Engine. Tangye's (Willan's Patent) three-inch three cylinder steam engine with vertical boiler, feed pump for same, and all fittings complete, on one base plate.

Tangye Brothers and Holman.

This engine is of the simplest construction possible; it is self-contained, has neither eccentrics, separate slide valves, nor piston rod guides, and can be driven at a very high rate of speed without the slightest noise.

2212. Steam Engine. 6-horse power expansion portable steam engine, fitted with Head and Schmidt's patent straw burning apparatus and patent automatic governor expansion gear.

Ransomes, Sims, and Head.

By means of this patent invention all kinds of vegetable substances can now be used as fuel in a portable steam engine, such as straw, reeds, dry grass, cotton and maize stalks, brushwood, &c., and by removing the patent apparatus the engine can also be fired with wood or coal in the ordinary manner.

This engine is also fitted with a separate expansion slide valve, and Brown's patent automatic governor expansion gear, which consists of a link motion attached direct to the expansion valve, and under the control of the governor, by means of which the amount of steam admitted into the cylinder is varied instantaneously in exact proportion to the work to be performed by the engine; an arrangement of the utmost importance in all cases where the load on the engine is suddenly increased or diminished, or where exact regularity of motion in the machine which is being driven is essential to success. The engine has also a simple and efficient arrangement for heating the feed water by means of the exhaust steam, and is provided with two safety valves, steam pressure guage, and all the most modern and complete fittings and accessories.

2212a. Two views of Ramsbottom's Pick-up Troughs at Whitmore.

F. W. Webb, Locomotive Department, London and North-westerm Railway, Crewe.

These troughs are laid down to supply the tenders of the locomotives with water whilst running; a dip pipe on the tender is lowered into the water, which thus runs into the tank, by this means saving time during the journey.

2212b. Dignity and Impudence (after Landseer). *F. W. Webb.*

This photograph represents the largest and smallest locomotives employed by the London and North-western Railway Company. The following dimensions of them may be interesting :—

	Dignity.	Impudence.
Size of cylinders - - -	$17\frac{1}{2}$ in. × 24 in.	$4\frac{1}{4}$ in. × 6 in.
Diameter of driving wheels -	8 ft. 6 in.	$15\frac{1}{4}$ inches.
Gauge - - - -	4 ft. $8\frac{1}{2}$ in.	18 inches.
Weight in working order - -	$28\frac{1}{2}$ tons	$2\frac{1}{2}$ tons.

2212c. Train used at the **Break Trials,** near Newark, June 9th to 15th, 1875 (2 photos.). *F. W. Webb.*

The train represented was one of the ordinary express passenger trains, fitted with continuous break, sent by the London and North-western Railway Company, to take part in the break trials at Newark in June 1875, before the Royal Commissioners.

2212d. Section of Tabular Results showing the Wear of Steel Rails. *F. W. Webb.*

2212e. Lovell's Patent Apparatus for recording the bad joints on railways and tramways. *Garnham & Co., London.*

This invention is for the purpose of showing the faulty joints in the permanent way, thus providing a means, hitherto unprovided for, for showing in the case of broken springs, or the oscillation of a train, on which side the fault rests, whether in weak springs or bad joints, and consists of a clockwork movement, arranged to draw an endless paper over suitable drums, in combination with a pencil. The indicator is attached between the spring and footplate of an engine or other vehicle, the pencil making a longitudinal line when no oscillation, and a vertical line when oscillation, takes place. The length of such vertical line is various, according to the amount of such oscillation.

2212h. Six Wheels coupled Mineral Engine. Size of cylinders, 17″ dia., 24″ stroke. Diameter of wheels, 4 ft. 3 in. Total weight in working order, 29 tons 11 cwt. *F. W. Webb.*

The barrel of the boiler and fire-box casing are of steel, and the axles and many of the working parts are also of steel.

2212i. Four Wheels coupled heavy Express Passenger Engines. Size of cylinders, 17″ diameter, 24″ stroke. Diameter of coupled wheels, 6 ft. 6 in. Total weight in working order, 32 tons, 15 cwt. *F. W. Webb.*

The frames, barrel of boiler, and fire-box casing, are of steel, and the axles and many of the working parts are also of steel.

2212j. Four Wheels coupled Passenger Engine, for heavy gradients. Size of cylinders, 17″ × 24″ stroke. Diameter of coupled wheels, 5 ft. 6 in. Weight in working order, 31 tons, 8 cwt. *F. W. Webb.*

The barrel of the boiler and fire-box casing are of steel, and the axles and many of the working parts are also of steel.

2212k. Fog Signal, universally used on railways. *E. A. Cowper, Westminster.*

This fog signal consists of a small flat tin box, having a little gunpowder inside, and some matches, which ignite on the box, being crushed by the wheel of a passing train, so that a person on a railway can communicate with the driver of a passing train even on the darkest night or during a dense fog.

2213. Apparatus for showing the **Motion** of **Fluids** through **long Tubes.** *T. Hawksley.*

2214. Model of London and its Environs. Scale 12 inches to a mile. *John Fowler, Westminster.*

Made for the purpose of showing before Committees of the Houses of Parliament the railways existing or in course of construction during the year 1864 ; also the proposed system of the inner circle railway, comprising the Metropolitan Railway, the Metropolitan and St. John's Wood Railway, and the Metropolitan District Railway.

2215. Improved Method of Reversing Rolling-Mills. *Jeremiah Head, M. Inst. C.E.*

A separate piece is introduced between the clutch and each clutch wheel, and connected with the latter only by elastic arms. The shock which ordinarily takes place when the clutch is thrown into gear is thus prevented.

2215a. Photograph of a Coal-testing Station.

2215b. Description of experiments on Coal relating to steam producing power ; determination of the proper breadth for the spaces between the fire-bars, and treatment of the coal ; ashes ; weight per hectolitre ; specific gravity and texture of the coal. *Berggewerkschaftskasse Bochum (Bergrath Heintzmann).*

The coal experiment station is a central establishment for experiment on Westphalian coal, designed for giving exact scientific instruction as to the best uses of particular kinds of coal, and for ascertaining their comparative practical values.

2215c. Frisbie's Patent Feeder and Grate for feeding fuel up from underneath the fire into all descriptions of furnaces, fuel boxes, and fire grates, for saving fuel, securing an intense heat, and consuming the gas and smoke. *J. M. Holmes.*

This invention is designed for feeding fuel up from beneath the fire into furnaces and fire grates. No fuel is thrown upon the top of the fire, but into

a charger which rocks forward to the front of the furnace under the grate bars, when, upon turning a crank, a central shaft carries the charger back under a central opening in the grate, when a piston rises in the charger and pushes the fuel up underneath the burning mass above. When the piston rises level with the top surface of the charger, it is retained in place by a catch until a reverse motion of the crank brings the charger again to the front, when the catch releases the piston and the charger is again ready for filling, the previous charge of fuel being sustained by a movable apron. The grate is constructed to revolve, so that any melted coal or slag can be brought to the door and removed quickly.

By this method the ignition of the fresh coal is gradual, and the volatilized coal, combustible gas, and carbonaceous matter pass from below through the live coals above, and break at once into flame, and the greatest intensity of heat is secured, and the gas and smoke consumed and a great saving effected.

2216. Model of a Blast Furnace Boiler, upon elastic supports. *Jeremiah Head, M. Inst. C.E.*

Long plain cylinder boilers, when hung as ordinarily upon rigid supports, are found to rise clear of the latter at their ends when in use, and in the middle when out of use. This leads to seam rips, and frequently explosion. By turning the small hand wheel right or left, it will be seen that, by the method exhibited, the boiler is able to modify its form without straining, and consequently without danger.

2216a. Model of a portion of the **Pontcysyllte Aqueduct,** which carries the Shropshire Union (late the Ellesmere) Canal across the river Dee, and the Vale of Llangollen. *G. R. Jebb.*

This model was made under the superintendence and direction of Telfords before the aqueduct was built. . . . The aqueduct consists of 19 arches, each having a span of 45 feet; the total length is 1,007 feet, and the height from the river Dee to the surface of the water in the canal is 127 feet. The foundation stone was laid on the 25th July 1795, and the work was finished in the year 1803.

This model having fallen into partial decay was a short time ago restored and repainted.

2216b. Model of an Apparatus for Exchanging Despatches on Railways, without Stoppage of the Trains.
M. Cacheleux, Paris.

2216c. Model of the late John Grantham's Patent Steam Tramway Car.

Also a detailed drawing of the above.
Mrs. John Grantham, Croydon.

2216d. Model Railway and Carriage, invented and made by Richard Roberts, C.E., Manchester, in 1824, to illustrate the nature of centrifugal force, in his lectures at the Manchester Mechanics' Institution. A practical model.
The Committee, Royal Museum, Peel Park, Salford.

X.—BRIDGE CONSTRUCTION.

2008. Diagrams for Bridge Construction :—

a. Resistances of materials, tension, and compression.
b. Girder on two supports.
c. Graphic treatment of arches for bridges.
d. Construction of iron bridges.

Prof. Heinzerling, Aix-la-Chapelle.

2009. Photographs for the study of Construction :—

a. Bauwaage (curves of construction), asymmetrical parabola.
b. Bauwaage (curves of construction), circle.
c. Bauwaage (curves of construction), segment of a circle.
d. Bauwaage (curves of construction), ellipse.
e. Bauwaage (curves of construction), aclinoid.
f. Bauwaage (curves of construction), cubic parabola—as lines of equilibrium. *Prof. Heinzerling, Aix-la-Chapelle.*

2092. Model of a roof. *Bock and Handrick, Dresden.*

2093. Model of a bridge. *Bock and Handrick, Dresden.*

2098. Model of Bowstring Bridge, thrown over the canal at Wormwood Scrubs, the tunnel of the Great Western Railway passing under the canal. *Council of King's College, London.*

XI.—COLLECTION OF MODELS AND DIAGRAMS ILLUSTRATIVE OF THE PRINCIPLES OF MECHANICS, ROYAL SCHOOL OF MINES.

2217. Mr. Shelley's Educational Diagrams on the Steam Engine.

2218. Educational Diagrams for illustration of **Applied Mechanics.**

Reciprocating motion in bullet-making machine.
Cams for bullet-making machine.
Machine for shaping plugs for bullets.
Reversing motion in rifling machine (2).
A parallel motion applied for rolling under pressure.
Pulleys connected by belts.
Angle of repose for various substances.
Screw press.

Dutch crane.
Differential motion.
Train of wheelwork in a crane.
A crane.
The Whitworth measuring machine.
A lathe.
Headstock of lathe.
Train for screw-cutting lathe.
Drilling machine.
Planing machine (2).
Slide rest for face lathe.
Blanchard's lathe.
Other shaping machines (3).
Arrangements for advancing boring bar.
The Cordelier.
Clock train.
Chronometer.
Regulator of watch.
Going fuzee of watch.
Rack lever escapement.
Detached lever escapement.
Chronometer escapement.
Gravity escapement.
Compensation pendulum.
Siemens' steam jet and the pneumatic despatch tube.
Principle of Giffard's injector.
Mode of supplying water to trains while running.
Air-pump of the Allen steam engine.
Husband's atmospheric stamp.
Steam hammers.
Hydraulic ram.
Cast-iron girder beams (2).
Beam of steam engine, right and wrong construction.
Girder bridges (5).
Locomotive (2).
Cylindrical boiler (2).
Marine boiler.
Forms of rail and wheel tire for locomotive (2).
Indicator diagram and slide valve of locomotive.
Hornblower's double cylinder engine.
Double cylinder engine, with piston valves.
Watt's disc valve and connexions.
Fairbairn's equilibrium valve.
High-pressure cylinder, piston, and valves.
Mode of receiving thrust of screw propeller.
Gauge, with corrugated plate, and india-rubber diaphragm.
Pendulum governor (2).

Pendulum governor applied to water-wheel.
Siemens' chronometric governor.
The forge bellows.
Blowing fan, with gauge.
Guibal's ventilating fan.
Centrifugal pump.
Turbine.
Water-wheel.
Hydraulic press.
The accumulator.
Pump worked by water pressure.
Hydraulic cranes (5).
Water pressure engine (as for crane).
Press for squirting metals.

2219. Mr. Anderson's Educational Diagrams on Mechanics.

Levers (12).
Wheel and axle (18).
Pulley (8).
Inclined plane (8).
Wedge (8).
Screw (10).
Dynamometers (3).
Toggle joint.
Virtual velocities.
Hydraulic press.
Elastic cords.
Pumps (2).

2220. Model to show the Conversion of Circular into Reciprocating Motion, in one direction only.

2221. Model to show the Conversion of Circular into Reciprocating Motion, in two perpendicular directions.

2222. Model to show Inequality of Motion, when a crank and connecting rod are used; also that the linear motion may be doubled when the connecting rod is equal in length to the crank.

2223. Diagram Model, with parts to illustrate the movements when the connecting rod is equal to the crank. Straight line motion.

2224. Three Models of an Eccentric Circle.

2225. Model to show Conversion of Circular into Reciprocating Motion, with intervals of rest.

2226. The Swash Plate.

2227. Crown Wheel Escapement.

2228. Simple form of Escapement.

2229. Recoil Escapement for Clocks.

2230. Dead-beat Escapement.

2231. Various forms of Escapement.

2232. Wheel, with one tooth and locking ring.

2233. Geneva Stop.

2234. Model of Recoil Escapement, for throwing an image on a screen by the electric lamp.

2235. Model of Dead-beat Escapement, for throwing an image on a screen by the electric lamp.

2236. Striking Movement of a Clock (locking plate).

2237. Striking Movement with Repeater.

2238. Model to illustrate Compensation Balance Wheel of Chronometer.

2239. Model of Wheel and Axle.

2240. Pulley Block.

2241. Disc and Roller Motion.

2242. Two forms of Screw Thread.

2243. Two Models to show the principle of Counting Machines.

2244. Counting Machine.

2245. Model to show Reversing Motion of the Table in Whitworth's Planing Machine.

2246. Model of Double Rack and Pin Wheel.

2247. Model of Cams in combination, taken from a machine for shaping plugs for bullets.

2248. Cam to Write the letters R.I. (Cowper's Model).

2249. Worm Barrel.

2250. Reversing Motion, with two and three spur wheels (quick return).

2251. Reversing Motion with Clutch.

2252. Model of Train of Wheels.

2253. Specimen of Spur Wheel.

2254. Two Models of Slit-bar Motion.

2255. Application of Slit Bar Motion in Whitworth's shaping machine.

2256. Two Models of Ratchet Wheels.

2257. Masked Ratchet Wheel.

2258. Silent Ratchet Wheel.

2259. Model to show Advance of a Ratchet Wheel through part of the Space of a Tooth.

2260. Ratchet Wheel, for traversing the cutter in a planing machine. Clement's Click.

2261. Machine for Printing Numbers.

2262. Drawing of a Lathe. (Whitworth.)

2263. Drawing of a Planing Machine. (Whitworth.)

2264. Apparatus to show that Friction is independent of Velocity.

2265. Apparatus to illustrate Friction Grips, and for experiments on the laws of friction.

2266. Model to show when a Drawer jams.

2267. Model to explain Weston's Friction Clutch.

2268. Silent-feed Motion (Worssam).

2269. Apparatus for illustrating the Angle of Repose between Two Surfaces.

2270. Plummer Block, showing Cylindrical Bearing.

2271. Form of Conical Bearing.

2272. Model of Friction Wheels.

2273. Model of Single Pulley Block.

2274. Two Models of Unbalanced Wheels.

2275. Model of an Arch.

2276. Model of Jointed Sword (Cowper).

2277. Model of Continuous Action Pump.

2278. Model of Pendulum, arranged for beating Time.

2279. Model for Tracing the Curves in the Slit Bar Motion.

2280. Two Models of Eccentric Rosette Motion.

2281. Various Models to show the production of Measuring Bars for End measure.

2282. Model to illustrate the conversion of Linear into End measure.

2283. Model to show Principle of Roberval's Balance.

2284. Balance on Roberval's Construction.

2285. Weighing Machine.

2286. Frame for experimenting with Epicyclic Trains, and with other trains, as in a screw-cutting lathe.

2287. Model of Combined Joints.

2288. Two forms of Ball and Socket Joint.

2289. Model of Hooke's Joint.

2290. Two Models of a Double Hooke's Joint, with adjustments.

2291. Mode of Connecting Parallel Axes.

2292. Parallel Axes, connected by a fork and grooved disc.

2293. Motion between Inclined Axes.

2294. Parallel Axes with Cranks and Links.

2295. Pair of Cranks, connected by a link, with adjustments.

2296. Mode of connecting Parallel Axes.

2297. Earliest Contrivance for feathering Floats in Paddle Wheels.

2298. Model of Link Motion in a Wool Combing Machine.

2299. Model of a Ventilating Fan.

2300. Model of Knuckle Joint.

2301. Knuckle Joint, with crank and connecting rod.

2302. Model of Stanhope Levers.

2303. Model of Lever Shears.

2304. Circular into Reciprocating Motion, with four beats for each rotation.

2305. Circular into Reciprocating Motion, with alternate intervals of rest.

2306. Model of Screw Surface.

2307. Model to show Difference of Inclination in Screw Threads of the same pitch, traced on cylinders of different diameters.

2308. Model of Endless Screw and Worm Wheel.

2309. Rolling Contact between Hyperboloids, with generating line mounted separately.

2310. Model of Skew Bevels.

2311. Two Axes, connected by a cord and grooved pulleys.

2312. Chain and Pulley.

2313. Pantograph, for drawing similar curves.

2314. Model of Watt's Parallel Motion.

2315. Model to illustrate the principle of Watt's Parallel Motion.

2316. Outline Model of Beam Engine, with Watt's parallel motion.

2317. Model of Roberts' Parallel Motion.

2318. Model of Peaucellier's Straight-line Motion.

2319. Sectional Model of a Trunk Engine.

2320. Model showing Expansion Valve.

2321. Model of Watt's Pendulum Governor.

2322. Model of the Cataract as applied to single-acting engines.

2323. Model of Silver's Marine Governor.

2324. Cornish Crown Valve.

2325. Hawthorn's Safety Valve.

2326. Richard's Indicator.

2327. Diagram Model for setting the Slide Valve of a Horizontal Engine.

2328. Mode of reversing Marine Engine by a single eccentric.

2329. Model of Stephenson's Link Motion.

2330. Model of Steam Pump with Valve inside the Piston.

2331. Sectional diagram Model of the Pump.

2332. Giffard's Injector.

2333. Model of Slide Valve and Ports.

2334. Right and left handed Screw.

2335. Models to illustrate Ferguson's Paradox.

2336. Model to illustrate Silver's Marine Governor.

2337. Three Bevel Wheels forming Epicyclic Train.

2338. Model to explain the Differential Dynamometer.

2339. Differential Motion.

2340. A Geometrical Pen, showing application of an epicyclic train to the drawing of curves.

2341. Model to illustrate the principle of the Geometrical Pen.

2342. Model to illustrate Rope-making.

2343. The Cordelièr.

2344. Model of expanding and contracting Crank.

2345. Model of Differential Pulley (Saxton's Patent).

2346. Lazy Tongs.

2347. Model for generating a Cycloid.

2348. Model of Headstock of a Lathe.

2349. Model of Collier's Planing Machine.

350. Model of a Drilling Machine.

2351. Two Models illustrating Whitworth's Drilling Machine.

2352. Model of Eccentric Chuck.

2353. Model to illustrate Houldsworth's Differential Motion.

2354. Model of Screw Propellor.

2355. Model of a pair of Locomotive Wheels.

2356. Model of Hindley's Screw.

2357. Rolling contact between Ellipses.

2358. Elliptical Wheels, for obtaining a quick return in shaping machine.

2359. Variable motion from Wheels set eccentrically.

2360. Model of Roemer's Wheels.

2361. Method of altering or stopping the reciprocation of an Arm without stopping the prime mover.

2362. Model for comparing Bourdon's Gauge with Mercurial Pressure Gauge.

2363. Model to show principle of Bourdon's Gauge.

2364. Model of Wave Line Cam.

2365. Model of Heart Cam.

2366. Cam with Pulleys and Band.

2367. Model to illustrate Slit Bar Motion.

2368. Model of Spur Wheels.

2369. Model of Perrault's Wheel and Axle.

2370. Model of Blowing Fan.

2371. Model of Centrifugal Pump.

2372. Model of Screw.

2373. Model of Pump with revolving Belt.

2374. Model to explain the Hydrostatic Press.

2375. Whirling Table for Suspended Objects.

2376. Models of Pyramid, Cone, Cylinder, Ring, Chain, and weighted piece, for experiments on rotation.

2377. Whirling Table.

2378. Model to show effect of Rotation on a cork and a bullet in tubes of water.

2379. Flask arranged for experiments on Rotation.

2380. Model to explain Siemens' Water Governor.

2381. Model to explain Ramsbottom's Velocimeter.

2382. Various Models showing effects due to Rotation.

2383. Apparatus for showing the effect of the atmosphere in causing a spherical bullet to deviate laterally.

2384. Balls swinging in a Cycloid.

2385. Models of Cone and Paraboloid.

2386. Two forms of Gyroscope.

2387. Model of Pendulum, with adjustments.

2388. Model of Accumulator, with Press.

2389. Sectional Model of Locomotive.

2390. Belt on Pulleys at right angles.

2391. Action of Convex Pulley on a Belt.

2392. Models to show the principle of Lattice Girder Beams.

2393. Whitworth's Bench Measuring Machine, to measure intervals differing by one ten thousandth of an inch, and for constructing difference gauges.

2394. Apparatus for obtaining a Rectangular Measuring Bar with plane ends at right angles to its axis.

2395. Hexagonal Surface Plates.